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THE PLIOCENE SKULL OF CALIFORNIA AND THE FLINT IMPLEMENTS OF TABLE MOUNTAIN

THE celebrated skull from Calaveras county, California, claimed to have been found at a depth of 130 feet in the auriferous gravel deposits of a Pliocene river "beneath the lava, in the cement, and in close proximity to a completely petrified oak" was exhibited by Professor J. D. Whitney at the Chicago meeting of the American Association for the Advancement of Science in the month of August 1868.

At that time the attention of the Association in general session was directed by the writer to certain conditions and peculiarities of the relic which made it unreasonable to accept it as coming from the deep gravels of a river. The objections then made to the skull as evidence of man's great antiquity do not appear to have been reported or recorded, having been given in the course of the discussion and not in a paper of record.

One chief reason for the rejection of the skull as coming from the gravelly bed of an ancient river is the entire absence on its surface, or on its broken edges, of any marks of attrition. If the skull had ever been rolled along the bed of a river with the bowlders and gravel, it would bear the marks of the violent pounding and wearing action to which any bone or object occurring in such gravels is subjected. In fact, a hollow bone or least

of all a human skull, could not remain intact, or even so well preserved a fragment as the skull in question, under such violent and abrasive conditions—conditions resulting in the rounding of the edges of pebbles and bowlders and in flattening out pellets of gold.

Those familiar with the auriferous gravel deposits, even of slight depth in modern rivers, know how the smaller materials fill every interstice of the bedrock, and, in the case of the bones of the mammoth and of the mastodon, how the foramens of the teeth and any cavity of the more solid bones of the jaw become filled up solidly with fine gravel, often cemented, and sometimes holding pellets of gold. Bones found in river gravels show the effects of attrition and wearing. All the thin plates, asperities, and sharp edges disappear under the violence to which they are subjected in running water transporting gravel.

In the Calaveras skull no such conditions are found. It was found hollow, nearly empty as left by the decomposed brain, not filled with gravel or sand, of a river deposit, and the broken edges were sharp and not abraded. This condition alone is sufficient evidence that the skull and the gravel in which it was said to occur were not parts of the same deposit and contemporaneous in origin in the river bed.

But certain objects were found in the skull—other bones, an ornament of some kind, and the shell of a snail, partially cemented together and to the skull by a deposit of calcareous tufa. All these objects indicate surface origin and interment, and their presence is not reconcilable with any theory of the entombment of the skull in auriferous, deep-seated gravel.

Since the exhibition of the skull at Chicago a full description of it, illustrated by a full-sized drawing, has been published by Professor Whitney.[1] By reference to this drawing it will be seen that all the fractured edges of the bones (for it is not an entire skull) are sharp and angular, and do not show signs of abrasion.

[1] Contributions to American Geology, Vol. I. The Auriferous Gravels of the Sierra Nevada, California, by J. D. Whitney, 4to, Cambridge [U. S.], 1880.

The presence of calcareous tufa is adverse to the theory of the occurrence of the bone in the deep gravel. The tufa is an incrustation; its presence indicates surface evaporation and concentration of calcareous waters. It does not occur in this case as a permeating solution forming a cement for deep gravel, but as an investing crust deposited on and around the bone, although it is claimed that a chemical change in the bone has resulted. The cementing material of the deep gravels is generally siliceous rather than calcareous, or if calcareous it permeates the mass and unites the pebbles and grains of sand into a rock-like mass.

The description states: "In cutting away the mixed tufa and gravel which covered the face and base, several fragments of human bones were removed, namely, one whole and one broken metatarsal; the lower end of a left fibula and fragment of an ulna as well as a piece of a sternum." "These bones and fragments of bones might have belonged to the same individual to whom the skull had appertained, but besides these there was a portion of a human tibia of too small size to be referred to the same person." There were also fragments of the bones of a small mammal. Under the molar bone of the left side, a small snail shell was lodged, partially concealed by one of the small human bones which was wedged into the cavity. This shell was recognized by Dr. J. G. Cooper as *Helix mormonum*, a species now existing in the Sierra Nevada. Cemented to the fore part of the roof of the mouth was found a circular piece of shell four tenths of an inch in diameter, with a hole drilled through the center which had probably served as an ornament. Several very small pieces of charcoal were also found in the matter adhering to the base of the skull."[1]

I have given this full quotation that there may not be any mistake. Professor Whitney is certainly to be commended for his complete presentation of evidence which is sufficient, in my judgment, to show that he was dealing with the relics of an Indian burial place rather than a fossil from the ancient gravels. It is not possible to conceive that this mixture of human bones

[1] *Ibid.*, p. 268.

of portions of at least two individuals, an ornament, charcoal, and a snail of an existing species, or of any species — a thin fragile shell — could travel together in the bed of a river and be concentrated in one spot, in fact, in one mass. It is incredible.

Much stress in the discussion upon the authenticity of this relic is placed upon the statement of the miner that he found the skull in his mine; that he found it there lying on the side of the channel with a mass of driftwood. While this statement of finding bones and driftwood together at that depth tends to discredit the statement it may be accepted, but with the question, how did the skull get there? The best explanation is found in the statement of another miner who had a claim in the vicinity that in going home one evening he picked up the mass, and, in passing his neighbor's shaft, threw it down to frighten him, and get him to go home to supper. The skull was then "discovered" and taken to Angel's Camp, where, after resting for a time in the window of the apothecary, it attracted the attention of Dr. Jones, of Murphy's camp, and was made known to the scientific world.

This is the story as told to me by eyewitnesses and participants. Thus the silent but convincing testimony of the skull itself, and of human testimony, are against its reception as evidence of man's antiquity.

But while the authenticity of this skull as a Pliocene fossil is questioned and challenged by most authorities, it is often accorded a quasi-recognition rather than an unqualified rejection. For example Professor G. Frederick Wright relying partly upon new evidence presented by Mr. Becker at the meeting of the Geological Society of America in 1891 appears to be convinced of the genuineness of the skull and states "it would seem unreasonable any longer to refuse to credit the testimony."[1]

The most satisfactory and common-sense discussion of the merit of this skull as evidence with which I am acquainted is that by Principal Dawson in his work enitled *Fossil Men*.[2] After

[1] WRIGHT, Man and the Glacial Period, p. 296.

[2] Fossil Men and their Modern Representatives, by J. W. DAWSON, LL.D., F.R.S., F.G.S., Montreal, 1880, pp. 344-347.

giving five cogent reasons for the non-acceptance of the Calaveras skull as evidence of the existence of man in Pliocene times he sums up as follows: "The above reasons are, I think, quite sufficient to warrant any geologist in declining to accept the human remains of the California gravels as other than those of American Indians of modern periods."

Quatrefages makes two references to the Calaveras skull. In one he writes: "Much has been said about the skull discovered by Whitney in California. Unfortunately, the description of this specimen has not appeared so that doubts have on several occasions been expressed as to the existence of the fossil itself. The recent testimony of M. Pinart has removed them, but has at the same time created the most serious doubts as to the antiquity of this specimen, which seems to have been found in disturbed grounds."[1]

Again, in discussing the succession of the two great types of skulls, he states "that at present everything argues in favor of the anteriority of the dolichocephali. In America the only known fossil skull leads to the same conclusion."[2]

In the foregoing citation of the conclusions of Dr. Dawson it will be noted that he groups together the evidence presented by the skull and those from other human remains in the California gravels. This tendency is shown, also, by Dana, who, after mentioning the doubts of the authenticity of the skull, writes: "Whitney also mentions the discovery of flint implements in the auriferous gravel in other parts of California. The fossil plants of the gravels are referred to the Pliocene (or partly Miocene) by Lesquereux. The few mammalian remains include the Champlain mastodon and elephant, but in some places Pliocene species. Some recent land shells were contained in the earth filling the cranium."

To anyone not familiar with the localities, the modern and ancient gravels, and the occurrence of flint implements, the

[1] A. DE QUATREFAGES, The Human Species. Int. Sci. Series, D. Appleton & Co., 1888, p. 291.

[2] Ibid., p. 299.

conclusion would, I think, be a fair one that both the mammalian remains and flint implements occur in the same gravels, or horizon, in which the skull is claimed to have been found. So far as my knowledge extends this is not so. I am not aware that it has been claimed that flint implements, or even the remains of the mammoth and the mastodon have been found where the skull was said to occur. That flint implements have been found in association with the remains of the large mammals there is little doubt, but as to the age of such gravels, and whether or not the implements may not have been washed in from higher levels or superficial deposits of a far later origin I am not able to bear conclusive testimony. The subject requires most careful and extended investigation, the fact being always kept in mind that in the gigantic placer mining operations of California there is a concentration upon the bedrock of all heavy objects which may have been originally in the surface soil or any part of the banks of gravel between the soil and the bed of the ancient river.

In all river and creek channels of modern streams, and even in what are called dry arroyos or gulches, there is a possibility that in seasons of flood or of great accumulation of rushing water from showers or cloud-bursts objects lying on the surface, such as stone implements, pestles, mortars, metates, flint chips, etc., may be swept onwards in the gravel and sunk to the very bed-rock and become buried by deposits twenty feet thick, and possibly more and all in the space of an hour or less. The loss of iron safes in different places in California and Arizona, the safes wholly disappearing, and similarly the loss of quicksilver in flasks while crossing a swollen torrent are familiar examples. Heavy objects, like gold, in swiftly moving water are carried to the lowest point possible and are covered from view by heavy deposits of gravel and bowlders. The finding, therefore, of Indian stone mortars at a considerable depth in gravel in a modern stream valley is not good evidence of antiquity.

In regard to the concentration of objects on the bedrock of placers, when there is sluicing or washing by the hydraulic method on a large scale, miners are familiar with the fact that

nails, spikes, shot and bullets are frequently found in cleaning up the sluices. In one instance, known to the writer, a small cast-iron casket containing the remains of an infant in alcohol was found in cleaning up a sluice after a long run by the hydraulic process upon a bank of gravel some thirty feet deep.

THE TABLE MOUNTAIN RELICS

Much has been written regarding the flint implements in great variety and perfection of workmanship collected from Table Mountain near Angels Camp by the late Dr. Snell. It was stated by him that they were found under Table Mountain, the lava cap of an old Pliocene river. I must confess to have for a time lent credence to this view of their occurrence. I reported the facts as I then understood them at the Congress of Archæologists at Paris in 1867.

But later investigations have satisfied me that these relics were entombed in the surface soil and accumulations of the slope of the mountain just below the jutting, overhanging cliffs of the lava, which afforded excellent protection from the weather, and were no doubt occupied as habitations or dwellings analogous to the cliff-dwellings of New Mexico and Arizona, but without any, now visible, exterior wall or construction. There is no reason for associating these flint implements in any way with the occurrence of the skull, or with the bones of the great mammals.

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A GRANITE-GNEISS IN CENTRAL CONNECTICUT

THE granite-gneiss[1] to be described occurs on both sides of the Connecticut River, some five miles east of Middletown. It cuts the schists of the eastern crystalline area of Connecticut, a short distance east of their contact with the Triassic sandstone. Its distribution is shown on the accompanying map (Fig. 1).[2] It forms an oval area in the mica schist, and, at its northern end, is continued northward by a series of beds varying from a few inches to many feet in thickness, lying parallel to the enclosing schists. The largest of these is a direct continuation of the main granite-gneiss mass, and all are probably parts of the same intrusion. As the distance from the main area increases, these beds gradually thin out and disappear from the schists.

The only previous work on the geology of this region is that of Percival,[3] who recognized this granitic rock only on the east side of the river, and united that part of it with a large mass of granitic-gneiss to the north, with which it is probably not connected. He does not consider the origin of any of the gneisses. It has not been possible to use Percival's results except in a general way, and the work done in this region by the writer is essentially *de novo*.

The rock is a medium to fine-grained biotite-gneiss. The color varies from white or light gray to dark gray, according to the amount of biotite. In a few cases the rock is almost or quite massive, but usually it is well foliated. The granite-gneiss is cut by several sets of joint planes, of which one set is nearly

[1] In this paper a gneiss of granitic composition and of unknown origin is called a granitic gneiss; if of igneous origin, a granitic gneiss. See C. H. GORDON in Bull. Geol. Soc. America, Vol. VII, p. 122.

[2] That portion of the western boundary of the granite-gneiss north of the river is largely covered by river terrace, and for about a mile along the eastern border, near Great Hill pond, outcrops are rare. With these two possible exceptions, the "supposed boundary," so-called, is believed to be very nearly the true boundary.

[3] J. G. PERCIVAL: Report on the Geology of Connecticut. 1842, pp. 222, 224.

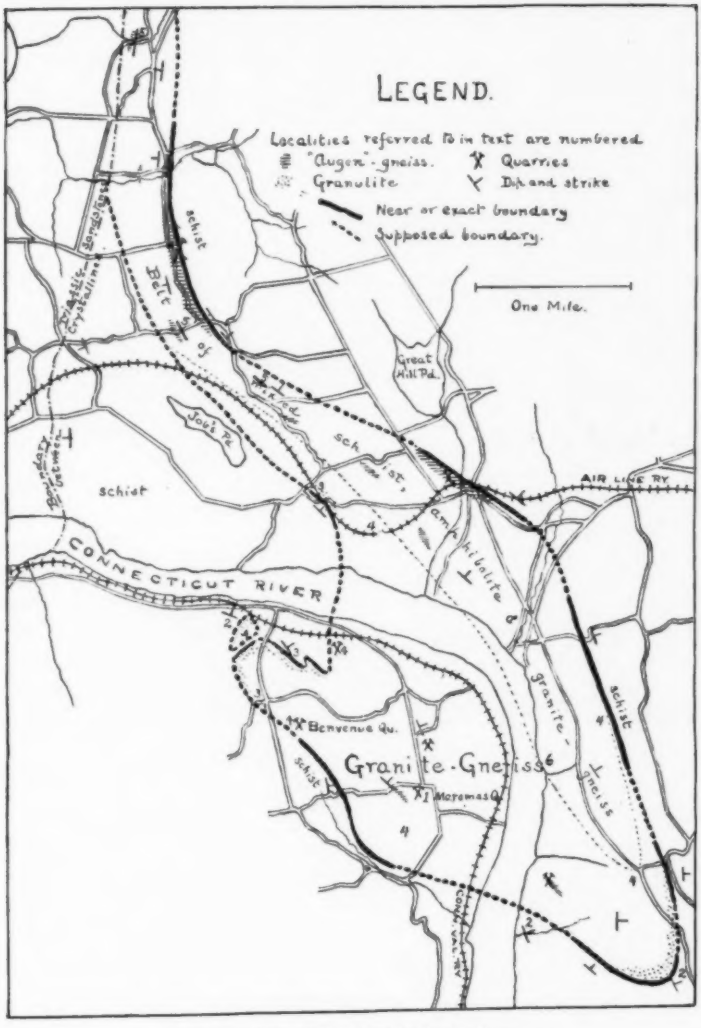


FIG. 1. Map of the Granite-Gneiss Area.

or quite parallel to the foliation, giving the rock a bedded appearance (Fig. 2. Map, 1). Several quarries have been opened, and the attempt has been made to market the rock as a building stone. It is handsome when first quarried, but stains quickly, and so is of use only for foundations, etc.

FIG. 2. Bedded Granite-Gneiss, Maromas Quarry.

I. THE GRANITE-GNEISS IS ERUPTIVE.

1. *General stratigraphical features.*—A rounded or elliptical form, like that taken by this granite-gneiss, is common in the case of eruptive granites. The narrow belt that runs into the schists from its northern end is decidedly subordinate to the larger mass of which it is an offshoot. The northwest direction of the longer axis of the granite-gneiss area is doubtless determined by the strike of the enclosing schists. The irregularity of the boundary on the west side of the granite-gneiss indicates

the same origin as does the general form of the area. At several points, too, along the western border and southern end of the granite-gneiss (Map, 2), the line of contact cuts across the strike of the foliation of the enclosing schists. This is not noticeable at all of the localities at which actual contacts between the two rocks can be seen, though it is at one or two, but it comes out on mapping the dip and strike of the schist. This foliation of the schists seems to be a stratification foliation and not a secondary structure, because (1) it is parallel to the alternating beds of schist and fine-grained micaceous gneiss which make up the schist formation, and (2) the dip and strike of the foliation is not uniform throughout the area, but varies through all possible changes.

2. *Contact Phenomena.* — At some of the localities where the exact contact of the two rocks is seen there is the clearest proof within narrower compass of the eruptive character of the granite-gneiss (Map, 3). The line of contact is frequently irregular, the granite-gneiss often cuts across the foliation of the schist or sends tongues into the schist; and sheets of schist, partly torn from the main schist mass, occur projecting into the granite-gneiss.

As the granite-gneiss occurs in the midst of completely crystalline schists, any considerable contact metamorphism of the surrounding rocks would not be expected. In many granite intrusions into crystalline rocks no contact metamorphism is seen. In the present case besides quartz, feldspar, biotite and occasionally hornblende, the schists carry at times garnet, staurolite, cyanite and tourmaline. The latter often seems to be connected with the pegmatite dikes which cut the schist. None of these less common minerals is more abundant near the contact or can be considered a result of the metamorphic action of the granite-gneiss.

It is sufficient merely to mention at this point another evidence of the igneous character of the granite-gneiss, namely, the fine-grained granulitic character which it assumes at some points about its border. This endomorphic metamorphism of the granite-gneiss will be described more fully below.

3. *Inclusions.*— One of the most striking proofs of the eruptive character of the granite-gneiss is the presence of inclusions of schist within its boundary. These are seen at a number of localities in widely different parts of the area, and commonly not far from the border (Map, 4). They vary in size from a few inches to many feet in length, and may be of linear or very irregular form. The material composing them is a biotite-schist, or a fine-grained biotite-gneiss, similar to the schist series around the gneiss and often showing the minute folding which in places is characteristic of the latter. The inclusions occur both in the more massive and in the more foliated varieties of the granite-gneiss, and also in the granulitic facies which occurs at some points about the border.

At this point it is well to describe an occurrence which, while not a proof of the igneous origin of the granite-gneiss, is best understood in connection with inclusions. At several localities in the southern half of the granite area, occur isolated bands of schist of uniform thickness, running parallel to the foliation of the immediately adjacent granite-gneiss. They cease at a greater or less distance, but their actual termination cannot be seen because of lack of outcrops. They show sharp contacts with the enclosing granite-gneiss and in one or two cases tongues of the latter enter them at a low angle, showing them to be inclusions. And as even those schist bands which do not show an apparent eruptive contact lie within an area of rock which is certainly in largest part eruptive, it is most likely that all such occurrences are inclusions. These band-like inclusions vary from a few feet to several score of feet in thickness, and are sometimes several hundred feet in length. Their direction is variable and is independent of the foliation of the schist lying nearest to them outside of the granite-gneiss area. Their sheet-like character was evidently determined by the strong foliation of the schists through which the granite-gneiss is here eruptive. It is, however, along the east side of the granite-gneiss that the amount of this foreign material is greatest. Here the mica-schist is associated with considerable dark,

thin-bedded gneiss and schist which contain both biotite and hornblende, and with amphibolite. These dark bands of gneiss and schist are not here variable in direction, but run parallel to the boundary of the granite-gneiss, and agree in dip and strike with the schist east of it and with themselves. Yet undoubted igneous contacts occur between these dark gneisses and schists, and the lighter granite-gneiss which occurs between them. The granite-gneiss which in other parts of the area replaced almost entirely the schist through which it came, here merely forced its way into fissures parallel to the foliation of the country rock. The distribution of this belt of mixed rock is shown on the map. As already pointed out the granite-gneiss gradually disappears as we go north.

4. *Schlieren.*—In a number of places where the granite-gneiss is most massive, it encloses patches of darker material or schlieren—basic segregations of the granite magma. These are best seen in the Benvenue and Maromas quarries. The schlieren are of uniform composition, finer grained than the enclosing rock, have a larger proportion of biotite, and often contain hornblende, which is almost wholly wanting in the ordinary granite-gneiss. They are rounded, elliptical or irregular in outline and always elongated parallel to the foliation so as to form lenticular patches and in extreme cases bands. This lenticular and frequently sheet-like form is probably due to movement in the partly differentiated magma previous to thes olidification of the rock. Such darker and more basic portions are very common in granites and have been regarded as a strong indication of the eruptive origin of the rock in which they are found.[1] In the Benvenue quarry where these schlieren occur, the rock also holds irregular inclusions of schist.

Associated Pegmatite Dikes.—Although the presence of abundant pegmatite dikes about a granitic area would not in itself be a proof that the rock in question was eruptive, it would be an interesting and corroborative fact. In the opinion of

[1] ROSENBUSCH: Massige Gesteine, p. 62; G. H. WILLIAMS, XV., Ann. Rept. U. S. Geol. Surv., p. 662.

Brögger,[1] Williams,[2] Crosby,[3] and others, the presence of one or more parent masses of less acid plutonic rocks is to be expected in such regions of abundant pegmatite dikes. The pegmatite dikes of central Connecticut are abundant, and are widely known for the variety and beauty of the minerals they have furnished collectors. They occur in dike-like masses in both gneisses and schists, but more abundantly in the latter, and they both cross and run parallel to the foliation of the enclosing rocks. Their contact with the gneisses and schists is sharp and they frequently contain inclusions of the same. There are two other considerable areas of granitic biotite-gneiss in the region, one to the south and the other to the north of the area under consideration. The former shows no sign of igneous origin and seems to be the basal member of a series of conformable gneisses and schists which form a northward pitching anticline. The study of the latter area is not yet completed. The evidence so far collected seems to indicate that it is largely composed of eruptive material; but even so the Middletown granite-gneiss is more centrally located with reference to the dikes and would more likely be the rock genetically connected with them. The schists which surround it are more filled with pegmatite. The hills near the Connecticut River, just west of the granite-gneiss, are known as the "White Rocks," from the prominent outcrops of pegmatite, and the schist east of the granite-gneiss is also cut by quantities of the same rock. This abundance of pegmatite dikes would lead us to expect one or more centrally located masses of granite with which they could be connected, and the area of granite-gneiss we have been describing seems to answer the expectation It does not appear that the dikes radiate from it; rather they follow in a general way the foliation of the schist. They do, however, appear to grow more abundant toward the granite-gneiss.

In connection with the evidence brought forward to show the eruptive nature of the granite-gneiss it is interesting to know

[1] Zeit. für Kryst., Vol. XIV, 1890, or Canadian Rec. Sci., Vol, VI, p. 33.

[2] Fifteenth Ann. Rept. U. S. Geol. Surv., p. 680.

[3] CROSBY and FULLER, American Geologist, Vol. XIX, p. 151.

that the granitic biotite-gneiss to the south, which has already been mentioned as constituting the lowest member of an anticlinal fold, and which appears from its field relations to be a sedimentary rock, wholly lacks the various characteristics of igneous origin possessed by the granite-gneiss. The mineralogical and structural characters which come out in a microscopical study of the rock, and which will be described below, are also in harmony with the belief that the granite-gneiss, in spite of its general and pronounced foliation, is an igneous rock.

II. PETROGRAPHY OF THE GRANITE-GNEISS

1. *The ordinary type.*—The ordinary form of the granite-gneiss is a light-colored, rather fine-grained biotite-gneiss. The amount of biotite varies considerably. Where it is most abundant, the rock is a dark-gray, well-foliated gneiss; where least abundant, the rock is light-gray and of a quite granitic appearance. In no case does it become perfectly massive. The grain of the rock allows of its being split along the foliation into curbstones, but not, as in the case of some of the other gneisses of the region, into flagstones. In the main body of the granite-gneiss the strike of the foliation is approximately N. 45° W.; the dip, 30° N. E. Joint planes cut the granite-gneiss in several directions, one nearly or quite parallel to the foliation, others at right angles. The rock is handsome when first quarried, but has proved useless as a building stone, because it rusts on exposure.

Microscopically the rock is a granitic mixture of feldspars and quartz, in which lie small plates of biotite. The biotite is abundant, generally with a pronounced parallel arrangement, to which the foliation of the rock is due. Hornblende is almost wholly absent. In a single section green hornblende occurs in amount subordinate to the biotite and it can be seen in a very few exposures in the field. The feldspars usually present an allotriomorphic, granitic aggregate of grains. Orthoclase is most abundant. An acid plagioclase is of common occurrence. Microcline also occurs in smaller and more irregular grains.

Both orthoclase and microcline frequently show a fine microperthitic intergrowth, with a second feldspar. In a larger number of sections some orthoclase and plagioclase grains show a granophyric intergrowth, with a second mineral, probably quartz, which takes the form of narrow irregular, curving or angular inclusions, converging toward the center of the feldspar grain. This granophyric intergrowth is absent from the probably sedimentary gneisses to the south, and seems to be characteristic of those of igneous origin. Quartz occurs in irregular but somewhat rounded interstitial grains, and is also common in drop-like inclusions in the feldspars, which occasionally approach a a dihexahedral shape. Titanite, in small, rounded, and lenticular grains, is the most common accessory. A very little apatite and magnetite occur. In about one half of the sections there is evidence of a slight amount of crushing. In the section where this is best shown, some of the quartz grains have been elongated, broken into separate areas, and granulated about their border and along lines of fracture; and between the feldspar grains are lines of smaller grains, which seem to have come from the fracturing of the feldspar. Yet in this section considerable portions show no evidence of crushing, and in many slides no proof of crushing exists.

2. *Schlieren.*— The biotite-gneiss, especially where it is more massive, often contains schlieren of darker color and finer grain, which have already been referred to and partly described in the discussion of the igneous origin of the granite-gneiss. Sections from these schlieren resemble closely the ordinary granite-gneiss. They are granitic in structure, but with a distinct foliation. Green hornblende is present, but is less abundant than the biotite. Orthoclase, plagioclase, and microcline occur in abundance in the order named. A few feldspar grains show the granophyric intergrowth already mentioned. Quartz and microperthite are absent. Titanite is a common accessory. The presence of hornblende and absence of quartz, while keeping the other essential structure and characters of the granite-gneiss, indicates that these darker patches are an integral part of the

granite-gneiss, only somewhat more basic than the general rock. The absence of any evidence of crushing in the sections shows that their present lenticular and banded form was attained while the rock was still unsolidified.

3. *The "augen"-gneiss.*— Frequently the granite-gneiss becomes a decided "augen"-gneiss. Its distribution is indicated as nearly as possible on the map. It attains its best development along the northeastern border of the granite-gneiss and in the narrow tongue that runs north into the schist. The "augen"-gneiss often passes gradually into the ordinary granite-gneiss, with which it is identical in mineralogical composition and in structure, with the single exception of the occurrence of sub-porphyritic feldspar crystals and aggregates. A surface broken at right angles to the foliation shows a light gray gneiss, dotted with more or less distinct "augen" of white or pink feldspar, averaging three fourths of an inch in length, and with a parallel arrangement, around and between which run the lines of biotite flakes. The feldspar of the "augen" often reflects light as a single crystal, either simple or a Carlsbad twin, and rarely this crystal is roughly rectangular, yet it never possesses crystal boundaries. Quite commonly the cleavage surface of these broken crystals shows dull rounded areas of feldspar which are differently oriented grains included within the larger crystal. Where a single crystal occurs it forms the irregularly margined core of the "auge" and is surrounded by a dull white rim composed of an aggregate of fine feldspar grains. As the core is pink and the rim white, there is a further contrast between the two. Much more often than not, however, the reddish core does not reflect as a unit, but consists of an aggregate of grains, still flesh-colored and coarser than the rim. In other cases the "augen" consist of aggregates of white feldspars without any reddish cores.

It looks very much in the hand specimen as if those reddish cores of the "augen," which are composed of an aggregate of grains, were derived from the fracturing of single grains, which in some cases seem to remain partly intact at the center. But

where such an aggregate is examined microscopically it is seen to be composed of feldspars of different species which show no evidence of crushing. One section (Fig. 3) showed such an aggregate consisting of a very irregular Carlsbad twin of orthoclase at its center, partly or completely enclosing irregular grains of orthoclase, plagioclase, and microcline, all containing small rounded grains of quartz. There was no evidence of crushing; no evidence of derivation of the smaller grains from

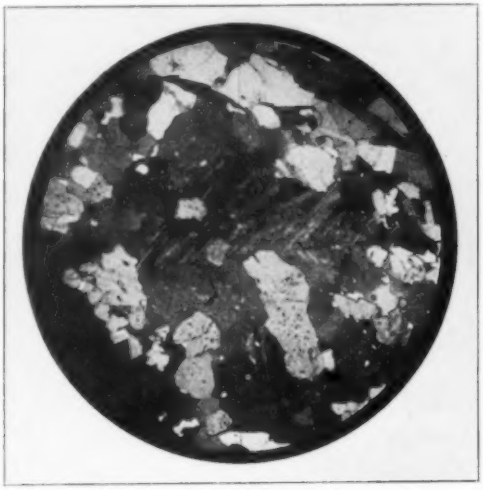


FIG. 3.—An "auge" of the "augen"-gneiss (× 18). The dark area on the upper right side is beyond the border of the section. Opposite, below, is the border of clear feldspar grains with a little biotite.

the central orthoclase grain. About this central aggregate was a zone of clearer feldspars. The red cores, then, of the "augen," both single grains and aggregates, are original crystallizations. The case may be somewhat different with the white rims which in many cases surround the red cores. These do show some evidence of crushing, and may be in part derived from peripheral crushing of the red cores, possibly accompanied by some recrystallization, for the feldspars here have a fresher appearance

than those in the central part of the "augen." Yet the absence of evidence of extensive crushing, and the fact that many of the "augen" consist wholly of white aggregates of feldspar which under the microscope show no evidence of crushing, lead us to suspect that even these white aggregates, which sometimes occur as borders around the red cores and sometimes constitute "augen" by themselves, may be, in large part, original crystallizations. The fact that these "augen" do not include to any extent plates of biotite, but that the lines of biotite flakes curve around them, seems to point to the formation of the "augen" previous to the complete solidification of the rock. The "augen"-gneiss, like the granite-gneiss of which it is a local variation, is of igneous origin. If we suppose that the first step in its formation was the separation of small orthoclase individuals or aggregates of feldspar, mainly orthoclase, but containing plagioclase and microcline, which received their parallel arrangement before the final solidification of the rock, and which may have been subsequently somewhat reduced by crushing, we shall have the most probable explanation of the "augen"-gneiss phase of this granite-gneiss.

The foliation of the granite-gneiss does not seem to be in the main a dynamic result. Evidence of crushing is found in many sections in the form of wavy extinction of the quartz and lines of finer material between the larger quartz and feldspar grains, and crushing may be responsible in part for the parallel structure of the rock. Yet in many sections of the well-foliated gneiss the microscope shows no evidence of crushing at all. It seems more likely that the arrangement in a common plane of the biotite and, in the "augen"-gneiss, of the often rather tabular grains of orthoclase is a result of movement in the partly solidified magma. The character of the schlieren points to the same conclusion. In ordinary granites the schlieren are not stretched, but are roughly equidimensional, and such we may suppose their original form to have been in the present case. Had they been drawn out to their present distorted condition subsequent to the solidification of the rock, they could hardly

fail to show evidence of such a movement in the distortion and crushing of their individual mineral particles, but such is not the case. And a rock subjected, while still incompletely solidified, to such an extensive movement as is indicated in the present instance by the form of the schlieren, would naturally have the elements which had already crystallized out, in this case biotite and, locally, individual grains and aggregates of feldspar, arranged in a more or less parallel manner.

4. *Granulite.*—For a mile along its western border, and for a somewhat greater distance about its southern end, the granite-gneiss shows a granulitic facies towards the contact. At other points both the "augen"-gneiss and the ordinary granite-gneiss may occur unchanged in immediate contact with the schist. The width of this granulite border is not constant; it varies from two or three feet to many yards. Where typically developed, it is a fine-grained, light gray or brownish rock, sometimes pure white and lacking all traces of dark minerals. This pure white granulite is present only at a few places and immediately at the contact. Small garnets are usually present. The rock has asugary texture, and when somewhat weathered often crumbles under the pressure of the fingers. Microscopically it is a fine-grained aggregate of orthoclase, an acid plagioclase, microclineand quartz. The structure is the so-called granulitic of M. Levy[1] and the panidiomorphic of Rosenbusch.[2]

The quartz and feldspar form an aggregate of variously oriented rounded grains of uniform size, which are not, however, bounded by crystal planes. With the scarcity of biotite, the foliation becomes indistinct or wanting. In one case garnet grains form fine lines on the broken edge of the rock. No evidence of crushing exists.

[1] M LÉVY: Classification des Roches Éruptives, p. 30.

[2] ROSENBUSCH: Massige Gesteine, p. 461. In this connection see TURNER: Geology of the Sierra Nevada, Sixteenth Ann. Report U. S. Geol. Surv., Pt. I, p. 737. Granulite (M. Lévy) is synonymous with aplite (Rosenbusch). Rosenbusch regards aplites as typically dike rocks, yet recognizes their occurrence as acid border phases of granite intrusions. *Ibid.*, p. 65.

At several localities the granulite can be followed from the contact and can be seen to pass gradually into the ordinary granite-gneiss. The changes on passing from the contact are as follows: (1) The rock becomes coarser, loses its granulitic structure and assumes a granitic structure. (2) The garnet disappears, biotite becomes abundant and is accompanied by the ordinary accessories of the granite-gneiss, titanite, magnetite and apatite. (3) Small grains of granophyre and microperthite

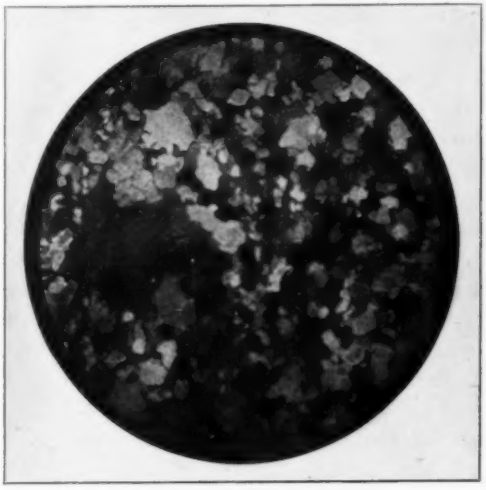


FIG. 4. Granulite (×18).

appear. These are common among the feldspars of the granite, but are wholly lacking in the granulite. Of these characters the granulitic structure and the presence of garnet extend farthest from the contact and often at a distance of many yards the richly biotitic granite-gneiss becomes garnetiferous and shows a decidedly saccharoidal texture.

Bands of granulite occur interbedded with or cutting across the schists near the contact. These bands are often less than an inch in thickness, and may connect with the main mass of the

granulite. A few of the smaller bands contain much muscovite and are well foliated. The granite-gneiss sometimes assumes a granulitic facies about inclusions. A good example of this occurs at one end of the Benvenue quarry, west of the river. A fifteen-foot mass of schist is caught in the granite-gneiss, which is dark gray and thick-bedded, but at the contact with the schist-inclusion changes to a fine-grained, white granulite with minute scattered flakes of biotite.

The eruptive nature of the granulite is clear. It cuts across the bedding of the surrounding schists; it sends apophyses into them; it holds inclusions of them. That it forms one geological body with the granite-gneiss is shown by its gradual passage into the latter at several points. It is not a crushed granite, as its position about the border of the granite and the absence of any microscopical evidence of crushing would show. It is an example of original endomorphic contact-metamorphism of the granite-gneiss,—more acidic and finer grained than the main body of the rock. The fineness of grain and the granulitic structure may be due to more rapid cooling of the magma in the neighborhood of the contact, though there is no reason why the conditions and consequently the structure of the granite-gneiss should be different at these points from what they were about the whole border of the granite. The more acidic character of the rock at the contact has not been satisfactorily explained. Similar phenomena have been observed elsewhere,[1] notably about some of the granite intrusions of France.

Besides the contact granulite described above, granulite occurs in three distinct forms. It occurs (1) as bands, generally not over a foot in thickness, cutting the granite-gneiss in or across the foliation and often becoming coarser and somewhat pegmatitic. In many cases these bands appear to grade somewhat abruptly into the surrounding rock. They are in a sense later than the granite wall-rock and may mark a closing stage of igneous activity, before the granite had fully hardened. It

[1] ROSENBUSCH, Massige Gesteine, p. 65. References to articles by BARROIS on several of these granites are given on p. 14.

occurs (2) as a white, fine-grained granulitic portion of some of the pegmatites. (3) One or several dikes of gray granulite cut the dark gneisses which occur associated with the granite-gneiss along its northern border (Map, 5). Their position is shown on the map. Each of these varieties has its own peculiarities and all differ from the contact granulite. They are probably all later than this last and are merely mentioned here for the sake of completeness.

5. *Darker and more foliated granite-gneiss.*—Along the northeastern side of the granite-gneiss area is a belt which has already been noticed, in which the granite-gneiss alternates with schists and with dark, more or less hornblendic gneisses and amphibolites. This area is indicated on the map. Associated here with the granite-gneiss and with these other rocks is a third type, in a way intermediate, yet more closely related to the granite-gneiss. These last rocks are darker and more foliated than the granite-gneiss. They are frequently marked by lenticular-linear white patches, up to a third of an inch in thickness, composed of an aggregate of feldspar grains. From this character they may be named "spotted-gneiss." They agree microscopically in structure and in mineral composition with the granite-gneiss. There are only two differences: (1) an increase in the amount of biotite and, as a consequence, a better developed foliation, and (2) the presence in some cases of hornblende. Sometimes they show microscopical evidence of crushing. They form eruptive contacts with the schists which are cut by the granite-gneiss.

The relations of the spotted-gneiss and the amphibolites are not wholly clear, and these relations are probably different in different cases. The two rocks are distinct petrographically. The contact between the two is an eruptive contact. If the amphibolites are older—and their stronger banding and foliation might well suggest as much—it matters not to the understanding of the granite-gneiss whether they are of igneous or sedimentary origin; they are in either case earlier rocks cut by the granite-gneiss. But in many cases they are probably later.

For eruptive amphibolites occur abundantly in the schist and presumably sedimentary gneisses outside the granite-gneiss area, and at one point within the granite-gneiss (Map, 6) banded amphibolites occur grading into massive hornblende-gabbro, and this basic rock becomes finer grained toward the contact where it cuts across the foliation of the granite-gneiss. Some of these amphibolites, then, are certainly younger than the granite-gneiss and cut it. Some may be older than the granite-gneiss.

The relation of the spotted-gneiss to the more ordinary granite-gneiss is not altogether clear. In some cases parallel bands of the two lie in sharp contrast. Again within limited areas a complete series of intermediate rock types occur. The spotted-gneiss seems to be a somewhat more basic rock derived from the same magma as the granite-gneiss. In part, however, it looks as if the two were not strictly contemporaneous. The spotted-gneiss may have been intruded into the granite-gneiss, or *vice versa*, although both find their origin in the same molten body and were the products of a single igneous intrusion.

LEWIS G. WESTGATE.

SOME NOTES ON THE LAKES AND VALLEYS OF THE UPPER NUGSUAK PENINSULA, NORTH GREENLAND[1]

INTRODUCTORY STATEMENT

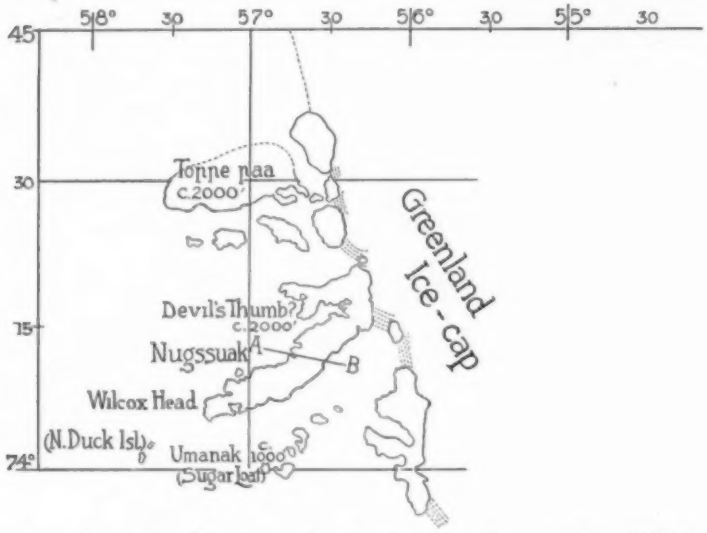
THE Upper Nugsuak peninsula is located in north latitude 74° 5′–15′; is 25 to 30 miles long, averaging from four to six miles in width, and has a due southwest trend with the general coast line of Greenland. This part of the coast is characteristically rough and rugged. The marginal strip — at present ice-free — is intersected by numerous fjords, which, in many cases, penetrate to the very edge of the ice-cap, cutting the uncovered land into numerous islands and peninsulas. A considerable part of the uncovered lands is occupied by lakes.

The peninsula is limited on its north and south sides, by fjords descending to depths of not less than 300 to 500 fathoms, and varies in elevation up to nearly 3000 feet. The hilltops have a general elevation of 1000 to 2000 feet. Its surface is a very rough and irregular one; is cut up by a network of deeply incised valleys, the seaward extension of which add to the ruggedness of the coast line.

The general appearance of the inter-valley areas — hills and ridges — is that of a well rounded moutonnée form, which prevailingly show among the lower hills a highly polished surface, while the higher peaks are as uniformly angular, and are very much less subdued topographic types. Some of the valley slopes are steep, often times precipitous, often with large talus

[1] The writer wishes to express his indebtedness to the Cornell University Expedition of 1896, under the directorship of Professor R. S. Tarr, and of which the writer was a member, when this work was made possible. Further acknowledgments are due Professors R. S. Tarr and A. C. Gill, and Messrs. E. M. Kindle, J. O. Martin and J. A. Bonsteel for valuable aid and suggestions — especially Professor Tarr, who kindly read and criticised this paper in manuscript.

heaps at their bases. The slopes have been trenched and furrowed by running water derived from the melting ice and snows. The scarred and shattered surface everywhere testifies to the great rapidity of frost action. The results of glaciation are conspicuous over all its parts, attesting the fact that the ice-cap has over-ridden its entire surface at some previous time. Remnants of local glaciers still exist among the higher peaks of its north-



ern border. Bowlders are abundant, while the paucity of till is quite marked.

Owing to much variation in texture, the intimate relationship of rock structure to topography is well marked, as shown in the case of the dikes of basic rock — diabase (?) — found cutting the gneiss in various directions. The gneiss has been intricately folded and contorted.

LAKE CLASSIFICATION

No large lakes are found on the peninsula. The basins vary in size from one and a half miles in length down to the merest

pool. The largest water bodies are confined for the most part to the large valleys; but many tarns are scattered over the higher lands. Both types are, with one or two possible exceptions, true rock-basins, since they are entirely surrounded by rock in place; for there is rarely enough till for a dam. Based primarily on origin, the lakes are grouped under "Rock-basins due to glacial origin," and on position, are further grouped as (*a*), highland, and (*b*), valley lakes.

ROCK-BASINS OF GLACIAL ORIGIN

The highland lakes.— On account of their salient features, not all the highland lakes can be ascribed as the direct products of glacial erosion; but it is certain that all of them owe their origin, either entirely or in part, to glaciation. Therefore, since this class is in part directly and in part indirectly the products of glaciation, and since no differentiation of those that are ice-scoured basins from those that are perhaps only partially due to glaciation, can be effected, they are both grouped as highland lakes of glacial origin.

This entire group of lakes is composed of small tarns and pools of very shallow depth. Their distribution is apparently controlled entirely by the weaker rock structure. Where the joint planes were numerous and intersected, tiny lakes were often found. Generally, the larger highland basins were found developed in the direction of the strike of the gneiss, and had resulted from the removal of the softer layers of gneiss, by some process of erosion. Still others were observed where these planes of weakness were not apparent, but, in some cases, could probably be ascribed to the result of chemical or mechanical weakness, due to mineral distribution. The lakes are prevailingly irregular in outline, and contain varying amounts of weathered débris scattered over the bottoms of their basins, which is very probably due to recent action.

Their size, distribution, position and intimate relationship to rock structure, and irregularity of outline are sufficient evidence of their having resulted, in part, from differential atmospheric

erosion. Scarcely any doubt exists against the large share of these tarns having resulted directly from differential ice scouring along the line of weaker rocks. In other cases, however, the basins have been more or less modified by the ice advance, which served to remove the preglacial decay, resulting in some instances, in a probable deepening from this cause.

Evidence has been brought forward by others, proving that not all trace of minor preglacial form was destroyed by the ice advance over portions of this and the Baffin land coast. Furthermore, that in its advance, all the preglacial decay was not removed, but that a somewhat roughened and irregular surface resulted from such action, mostly along the lines of rock weakness. To the combined action, therefore, of differential preglacial weathering and ice erosion, along the lines of weak structure, are due most, if not all, of the group of highland lakes.

Concerning the origin of this type of lake along the Greenland coast and other similarly glaciated lands in the arctic latitudes Professor Tarr says:[1]

> It is noticeable near Cumberland Sound, as well as in Turnavik, and in Hudson's Strait, and indeed in Greenland, that there are many basins of small size, surrounded entirely by rock. While some of these have no doubt been scoured out by differential ice erosion, the position of many of them along the lines of weaker rocks, indicates that they represent differential preglacial weathering. The advance of the ice in these cases has served to remove the

[1] TARR, R. S.: Amer. Geol. 1897, Vol. XIX, pp. 195, 196.

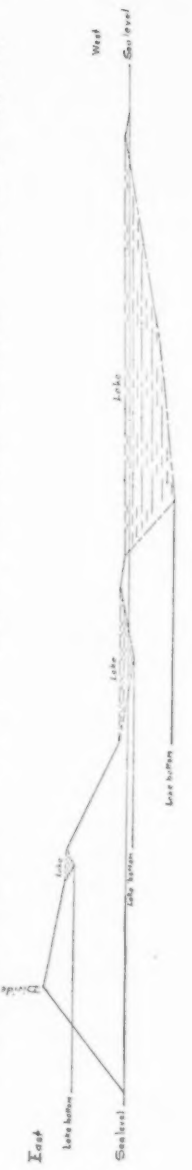


Fig. 1. Profile of valley marked AB
Scale 1" = [illegible] inches

decayed rock, and perhaps to deepen the depressions formed by this action, though ice erosion would not in this case be the prime cause for the basin.

These [rock-basins] seem to be depressions caused rather by preglacial decay than by glacial erosion. They are often so small and bounded by walls so angular that origin by ice scouring seems impossible.[1]

The valley lakes.—The line, marked "AB" on the map, indicates the position of one of the largest valleys on the peninsula, with seaward termination on the east and west sides, and is from three and a half to four miles in length. Fig. 3 shows cross-sections, with reference to sea level, of the east and west ends of this valley. "A" was sketched at a point in the valley 165 feet above sea level, while "B" is only 15 feet above. Neither of these has been platted to any scale. A glance at the two is sufficient to note the contrast in outline of the two ends of the valley. The south end, A, is filled in on all sides to an unknown depth with perfectly angular blocks of large dimensions. This difference in valley width for the two ends is due, probably, in a great measure, to preglacial conditions. It is more than likely, that the preglacial divide was located near the south end of the valley, with its western end farther down stream, and therefore wider. The west end of the valley is fully three fourths of a mile wide, with inclosing walls rising 1000 feet and more above the bottom, sloping at a steep angle—less than 45°.

The valley further holds the largest lakes distributed along any one of the valley bottoms (see Fig. 2). Careful soundings were made of all the lakes located in this valley, and two showed their bottoms to be considerably below sea level. The position in the lakes where soundings were taken are marked on Fig. 2. After the sounding data were obtained, several possibilities naturally suggested themselves to account for this condition, in the lakes. A close examination of all the conditions, however, resulted in the elimination of all save one of the possibilities. Stream erosion with subsequent depression is eliminated on the ground of extreme irregularity of valley bottom. On the north and near the west end of the valley, the attitude of the strata is

[1] *Ibid.*, Bull. Geol. Soc. Amer. 1897, Vol. VIII, p. 255.

FIG. 2

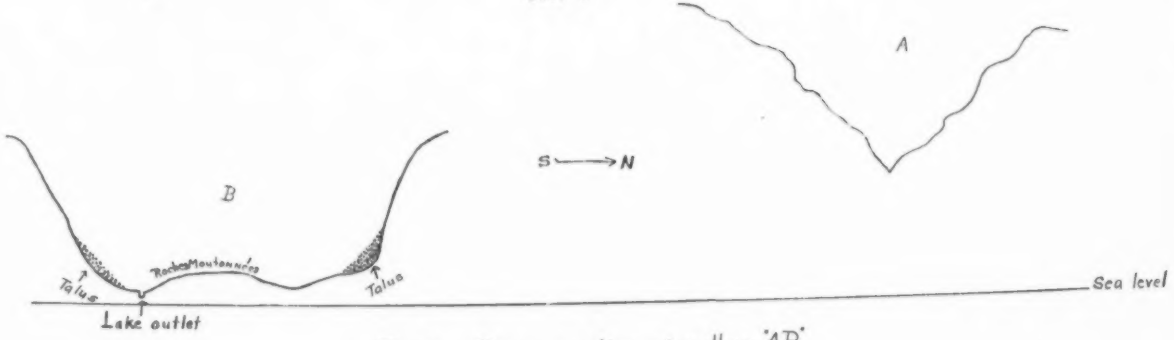


Fig.3. Cross-section of valley 'AB'.
A = E. end.
B = W. end.

that of an overturned fold, whose axis is at right angles to that of the valley. The position of the strata proved that at no point could the valley owe its origin to folding. Rock structure and position were also opposed to origin by differential weathering. The tracing of the same and equivalent strata on the two sides of the valley would preclude faulting. Damming by deposition of morainic material is untenable, since no moraines of any extent occupy any portion of the valley.

The only other possibility to account for these lakes is that of "*ice erosion.*" A brief description of the lakes in this series, with the closely associated glacial phenomena, will best show the evidence for their glacial origin.

The first lake is the only one of this series with bottom above sea level. It is located 60 feet below the valley divide and 165 feet above the surface of the middle lake. It is more or less saucer-shaped in outline, and is, with the exception of the east side, entirely inclosed between highly polished and striated moutonnée forms.

The middle lake, marked lake No. 2 of Fig. 2, lies immediately against the high, precipitous south wall of the valley, and inclosed entirely by moutonnée forms on its north, south, and west sides. It is entirely surrounded by rock in place with its bottom 39 feet below sea level. The moutonnée forms on the north side of the valley are highly polished and planed, with glacial grooves and striae greatly intensified, reaching from the lake's surface up to an elevation of 100 feet. These are coincident with the trend of the valley.

The space between the middle lake and lake No. 3 of Fig. 3, is occupied by moutonnée forms of well-rounded outline and slight elevation. Lake No. 2 drains into lake No. 3 through a rock channel some 50 yards across and about 100 yards long, carved between the close-lying moutonnée hills.

The lake occupying the west end of the valley lies, for most of its length, immediately against the high, precipitous north side. It is something over a mile in length, very narrow, and quite irregular in outline, closely resembling a stream. It is

15 feet above sea level, and in its deepest part — near its head — is 150 feet below sea level. Perfectly developed glacial grooves and striae, with direction coincident with the axis of the valley, extend for quite a distance along the south border of the lake. The outlet channel is cut into solid rock, and averages from four to five feet in depth, with a U-shaped cross-section. The overflow passes over a low point in the divide between the lake and fjord on the southwest side of the valley. The divide is highly glaciated, and stands 25 to 50 feet above the lake level. As can be seen from Fig. 3, the portion of lake near the outlet is dotted with moutonnées rising to a slight elevation above the waters and forming a group of small islands in the lake. Bowlders of varying dimensions are found poised in various positions over the tops of nearly all the largest roches moutonnées in this valley. It will be further observed that the valley axis, AB of map, is approximately coincident with a westward advance in the general glacial movement over the peninsula. Further, that the largest and deepest water bodies are located in the northwestern portion of the peninsula, which portion is shown in a subsequent part of this paper to have been subjected to a period of more or less intense local glaciation. On the high hilltops forming the southwestern limits of the valley are found remnants of once larger local glaciers.

As a class, the valley lakes observed on the peninsula, range in size from something over a mile in length down to the smallest size basin. In outline, some were saucer-shaped — width and length about equal — but generally the length greatly exceeded the width, and when so found were invariably characterized by irregularity of outline. They varied from a few feet to 150 in depth, and in all cases their circumferences were marked by rock in place, proving them to be true *rock-basin* lakes. With but few exceptions they are prevailingly shallow and filled, more or less around their edges, with rock fragments derived from the valley sides, due to shattering by frost. Approximately eight to ten feet above summer water level and along the edges of parts of a few of the larger lakes were noted slender but perfectly formed

beaches. These may represent storm levels, or they may be the result of climatic changes. While the valleys probably cannot in all cases be ascribed to the same cause, the lakes associated with the valleys are, apparently, the result of differential ice erosion, and are true rock-basins, since they are walled in by rock *in situ* on all sides.

Dust wells and pools on the ice-surface.—The marginal surface area of the glacier ice was found dotted with numerous circular holes, varying from a quarter of an inch to several feet in diameter, and averaging probably several feet in depth. These were filled nearly to their tops with water, and their bottoms were invariably covered with a thick layer of dust. Professor Barton[1] has described the same condition to the south of this locality in the Umanak district, where he states, that the pits are confined to a marginal zone of about one mile in width, beyond which, and towards the interior, the ice surface becomes comparatively smooth. Professor Chamberlin[2] has observed the same conditions farther north along the west coast, and has fully discussed their origin in a previous number of this JOURNAL.

Other larger pools were seen. Professor Tarr[3] noted an especially large one, occupying a depression in the ice, of about one quarter of a mile in length in the direction of its longest axis, very shallow in depth, and revealing clear smooth ice, with no sediment over its bottom. No observation was made concerning its outlet, and Professor Tarr states that the pool probably represents a case of differential meeting.

Lakes due to other causes.— Along the ice margin, lakes were found, in places, formed by the usual ice marginal processes. A majority of these marginal lakes are due to a walling in of the numerous depressions of the extremely irregular surface of the peninsula, by the more or less steep ice-front on one side, and the slopes of the depressions of the land on the other. Each of

[1] Op cit., p. 216.

[2] JOUR. GEOL., Glacial Studies — Greenland, IV, Vol. III, 1895, p. 215.

[3] Communicated by letter to the writer.

these was fed by a marginal stream flowing along the ice front, which was, in turn, made up from the numerous smaller streams flowing off of the ice at its front. In some instances the lakes had been recently drained revealing heavy and conspicuous silt deposits, which necessarily were irregular in position, as is characteristic of marginal lakes. Some were found draining through tunnel outlets in and under the ice.

Morainal formed lakes, both by means of the masses ponding back the waters, and as kettles occupying the depressions in the morainal accumulations, were not uncommon.

Lakes noted at other points.—Rock inclosed bodies of water similar to those on the upper Nugsuak were noted at the following points: Turnavik Island, off the middle coast of Labrador; Big Savage Island, Hudson Strait; Icy Cove, the extreme southern coast of Meta Incognita; Niantilik, Cumberland Sound; and at several places along the Greenland coast to the south of the Upper Nugsuak peninsula. So far as observation extended their origin and development have been essentially the same.

At Niantilik a large number of typical rock-basins, resembling in every respect the Nugsuak lakes, were observed. Where studied, these were found developed in true strike valleys, and in case of the larger ones, roches moutonnées islands of slight elevation and formed by the hard layers of steeply tilted gniess were found. The character of these lakes left no doubt as to their being true rock-basins formed in part by ice erosion. Their entire circumferences were in many cases encircled by rock in place.

THE VALLEYS

No grouping of the valleys according to direction could be effected, since they were found trending with all points of the compass. An apparent series of major valleys were observed, cutting the peninsula in a direction varying from an almost east and west course to one at nearly right angles to this, which invariably had a seaward termination.

In a very general way, the larger valleys are best described as being very deep and broad, somewhat U-shaped in outline.

There are wide variations, however, from the steep sided and precipitous profile to that of considerably gentler slope. Frost action has wrought widespread results on the original glacial outlines of this form, resulting generally in a modification tending toward a less precipitous outline.

It has already been stated that numerous dikes of a basic eruptive rock, probably diabase, are found cutting the gneiss in an approximately vertical attitude. The basic dike rock of the peninsula has yielded more readily to the attack of the atmospheric agencies than the inclosing gneiss. Subsequent ice advance removed most of the residual decay, resulting in some instances, in the ice eroding considerably below the line of actual decay, determining thereby one set of the major valleys. The U-shaped outline is especially applicable to this type of valley.

Similar conditions apparently prevailed at Turnavik, Labrador, as on the Nugsuak. The rock is a coarse porphyritic gneiss cut by dikes of a basic eruptive, many of which have been eroded to a depth of some 20 to 25 feet by the ice, and in some of which residual decay was still to be seen, indicating a greater preglacial decay of the dike than country rock.

In the Umanak district of North Greenland, Professor Barton,[1] observed that the dikes of eruptive rock had not been eroded below the level of the inclosing gneiss, but instead, they were found, in some instances, standing "out in relief above the gneiss."

No petrographic study has been made of the rocks in the localities mentioned above, hence it would not be safe to say whether the difference could be accounted for on lithologic grounds, or whether it is due to a difference in glacial conditions.

A second type of valley, but of minor importance, on account of slight development, was noted, the origin of which was traceable to the etching out of the softer rock layers in the highly tilted strata by differential atmospheric weathering, and can therefore be classed as strike valleys.

Subsequent to the period of widespread general glaciation,

[1] BARTON, GEO. H., Technology Quarterly, 1897, 10, 236, 237.

the northern ends of the valleys have undergone considerable modification from a period of local glaciation, which is now confined to the northern side of the peninsula, and in its last declining stage. Owing to the work of local glaciation, more or less contrast is observed in the topography of the opposite ends of the approximate northwest-southeast trending valleys (see Fig. 3). Glacial filling, principally bowlders with some till; abundance of typically developed roches moutonnées, glacial grooves, striae, planing and polishing, conspicuously characterize all of the major valleys.

A large number of the major valleys were associated with dikes of basic rock. So far as studies were extended, the mass of fact pointed to the conclusion, that this type of valley was due to differential preglacial decay with subsequent ice erosion. The entire set of major valleys, everywhere viewed on the peninsula, are distinctly preglacial; and while their origin was not apparent in every case, they have all suffered considerable subsequent modification from ice erosion.

A parallel is probably found in Canada, where Dr. Robt. Bell[1] has observed greenstone dikes protruded into granites. The dikes have subsequently been worn out and at present form valleys occupied by lakes and streams.

THOMAS L. WATSON.

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Atlanta, Georgia.

[1] BELL, DR. ROBT., Bull. Geol. Soc. Amer. 1894, V, 364.

AN ATTEMPT TO FRAME A WORKING HYPOTHESIS OF THE CAUSE OF GLACIAL PERIODS ON AN ATMOSPHERIC BASIS

(Continued)

SPECIAL APPLICATION OF THE HYPOTHESIS TO THE KNOWN GLACIAL PERIODS

IT now remains to specifically apply the hypothesis to the recognized glacial periods. At present only those at the close of the Paleozoic and Cenozoic eras are sufficiently determined to require discussion.

The mapping of the Pleistocene glacial deposits is sufficiently complete to show their great features, and reveals a strong development in the northern hemisphere, and at the same time a quite peculiar localization. The analysis of the deposits has progressed far enough to show that the glacial period was marked by pronounced oscillations of both the major and the minor kind. Interglacial epochs of a declared character may be assumed to be fairly demonstrated, while the glacial epochs themselves were attended by rhythmical stages of progress, as most pointedly brought out by recent detailed field work in the Mississippi and St. Lawrence valleys, notably that of Mr. Leverett and of Mr. Taylor. These rhythmical features are made the subject of a special discussion by Mr. Taylor in a paper entitled "Moraines of Recession and their Significance in Glacial Theory."[1]

To be really applicable to Pleistocene glaciation a working hypothesis must therefore not only postulate agencies capable of producing a glaciation covering the American plains down to

[1] JOUR. GEOL., Vol. V., No. 5, 1897, pp. 421–465. See also "The Great Ice-Dams of Lakes Maumee, Whittlesey, and Warren," American Geologist, Vol. XXIV, No. 1, July 1899, pp. 6–38, and the review of this paper by MR. GILBERT in the last number of the JOUR. GEOL.

37° north latitude, and mantling also the plains of middle Europe and high altitudes quite generally, but it must assign agencies for the oscillations which attended it.

General cause.—The atmospheric hypothesis finds a general cause for the Pleistocene glaciation in that notable extension and elevation of the land which reached a climax near the close of the Pliocene period. It is not, however, through its direct topographic influence that this was accomplished, though this may have been incidentally tributary, but through its effects on the constitution of the atmosphere. The recently named Ozarkian or Sierrian period embraces the specially effective stage of this great land area, and it is with much pleasure that I support the emphasis laid upon the significance of this period by Professor Le Conte in his paper in the last number of the JOURNAL,[1] though I interpret that significance in different terms. The wide extent and high elevation of the land at that time are so strongly set forth by Dr. Le Conte as to leave no need for additional emphasis here.

A rude estimate of the land area in Middle Tertiary times, when the climate was mild far to the north, gives about 44 million square miles. A similar estimate for the Ozarkian or Sierrian period gives about 65 million square miles, while the received estimate of present land is about 54 million square miles. Taking the Middle Tertiary area as a basis of comparison, the land was increased in the Ozarkian period about 47 per cent., and afterwards fell off to the present area, which is 23 per cent. greater than that of the mid-Tertiary. It is probably conservative to estimate that the average elevation of the Ozarkian land was at least two or three times, perhaps three or four times, as great as that of the mid-Tertiary. Combined in the light of the suggestions previously made regarding elevation, these indicate a very great change in the effective contact of the atmosphere with the earth. If we measure the actual contact by the surfaces of the grains, pores, fissures, and minute crevices with which the air and the atmospheric waters come in contact

[1] Pp. 525–544.

—and this is the true contact area—the increase will appear impressive.

As in other cases, there was here also a self-accelerating action. As land was elevated, its underground water level was at first carried up measurably with it and lay near the surface. Trench-cutting accompanied it, to be sure, but at a slower rate. As the declivity increased the cutting and transportive power of the drainage increased, and as the dissection of the land proceeded, the water level was lowered and the effective zone of atmospheric contact augmented. The very process of degradation, up to a certain stage, increased the facilities for the chemical action of the atmosphere. In general it may be observed that degradation reacts upon itself favorably for a time. The cutting of certain of the western plains into "bad lands" and the gullying of the cultivated fields in certain parts of the southern states are striking examples of current self-accelerating processes of the more mechanical sort.

Concurrent with this increase of the atmospheric contact-area on land there was a reduction of sea surface, the habitat of lime-secreting life, and, *nota bene*, an almost complete obliteration of the epicontinental seas and sea-shelves which were the parts of the sea bottom that were by far the most prolific in carbonic-acid-freeing marine life. Shallow-water marine life must have been very generally driven down on the abysmal slopes and on to such limited deeper shelves as may have been brought within reach by the lowering of the seas. The consequent lessening in the rate of freeing of carbon dioxide is assumed to have been great, and this coöperated with the accelerated consumption on the land to hasten the depletion of the atmosphere.

Besides this, when any appreciable reduction of temperature followed these coöperating agencies, it tended of itself to check the lime-secreting life of the ocean, and at the same time to give the oceanic waters greater absorptive power and less dissociative activity, thus calling into operation a group of secondary agencies which intensified the effects of the primary agencies.

Now the task assigned this remarkable combination of agencies is not a formidable one. If we take the largest of the current estimates of the present atmospheric content of carbon dioxide, viz. .06 per cent. by weight (comparable to .04 per cent. by volume), the mid-Tertiary atmosphere should have contained .15 per cent. to .18 per cent. of carbon dioxide, and that of the glacial period .03 per cent., following Dr. Arrhenius' estimates. That is to say, for the reduction of the carbon dioxide of the Tertiary atmosphere from the assigned .15 per cent. or .18 per cent. to the assigned .03 per cent. of the glacial period, we have an estimated increase of land area of 47 per cent., and an increase of elevation of 100 per cent. or 200 per cent., and perhaps more. To produce the present amelioration we have a falling off of about one half in each of these items.

Numerical data, which will be given later, indicate that something like $\frac{1}{2000}$ of the carbonic acid of the air is now taken out annually. If the same amount is returned, the constitutional status is preserved. But if the foregoing agencies that coöperated in late Pliocene and early Pleistocene times to disturb the balance between removal and return were effective to no more than 10 per cent. of the total rate, it would have been capable of reducing the assigned mid-Tertiary content of .18 per cent. carbonic acid to the assigned glacial content of .03 per cent. in 50,000 years. It is not, of course, supposed that the rate would be constant as the state of enrichment changed, and note of this will be taken later, but the computation serves to show how effective a disturbance in the relative rates of supply and removal becomes when such action bears so high a ratio to the total mass of carbon dioxide in the air. It may also serve to show that the hypothesis is assigning agencies whose supposable quantitative competency is abundantly adequate to the results imputed to them.

ASSIGNED CAUSES OF GLACIAL OSCILLATION

It has been already noted repeatedly that the assigned causes of glaciation are self-accelerating in certain significant

phases. The salient effect of this, reasoning on general principles, must be to push results to an extreme from which reaction is inevitable. Let us consider this in detail. It is thought that there were three dominant agencies concerned in this, modified by several subsidiary ones.

1. A necessary consequence of the accelerated rate of transmission of carbon dioxide to the sea, combined with a slackened rate of release in the sea, was an accumulation of oceanic carbon dioxide. The primary form of this was an increase of the carbonates.

2. The cooling of the sea waters which attended the process reduced the dissociation, and hence the carbonates were more nearly full bicarbonates than before. *There were, therefore, not only more carbonates, measured by the bases, but they carried more carbon dioxide in proportion to the bases.*

3. With the growth of the snow-fields attendant on the progress of glaciation, there was an increase of reflection of the sun's radiation and a reduction of its absorption. Computation shows that the albedo is an important factor.

Subsidiary to these there were the following:

4. There was an increase in the absorption of carbonic acid in the ocean, resulting from the lowering of the temperature. This, however, was offset by the declining partial pressure of the carbon dioxide in the air, and, as the two seem to be of the same order of magnitude, they may be set aside for the present.

5. With increasing cold there was a less rapid decay of organic matter and a less complete release of carbon dioxide. Over against this, however, there was a reduction in the amount of carbon locked up in living organic matter. It is difficult to form a trustworthy estimate of either, but it may be provisionally assumed that they belong to the same order of magnitude and may be set aside together. At any rate, any residual difference would not apparently be a notable factor.

6. The majority of chemical authorities state that the solubility of calcium carbonate in water saturated with carbonic acid increases with a lowering of temperature through ordinary

ranges. Unfortunately there is not complete unanimity on this point. But, if this be true, as the temperature fell the solvent action of the carbonic acid of the land waters upon the limestone was increased. Over against this was a probable reduction of the action of organic acids. Probably the decomposition of the silicates went on at a lower rate, but, as it was much less than one fifth of the whole action, its reduced rate is not very material here.

As the carbonic acid of the air was diminished, its action on the land surface declined—though not at a proportional rate—but long before it could offset the enlargement of the contact area aided by the sea action, glaciation would be far advanced, if the previous estimates hold good.

Setting aside, as being measurably balanced, or as being of minor or uncertain value, all but the first three items, which are clearly factors of great potency, we find at first a strong disposition toward the acceleration of the depleting process.

But this, although a pronounced influence in the early stages of refrigeration, could not continue indefinitely, for the process involved the conditions of its own arrest.

The arrest of the depletion and the inauguration of the reaction.—With the development of glaciation, the agencies that tended to counteract atmospheric depletion received a powerful ally in the ice-sheet itself. The spread of the ice over the surface prevented further effective weathering of the area so covered and correspondingly arrested atmospheric depletion. The total area covered by glaciation at its maximum was probably not far from 8 million square miles, or nearly 15 per cent. of the land surface.

Besides this, the area outside of that actually covered by the ice-sheets was probably affected by prolonged freezing during the winter stages, and was perhaps to some extent permanently frozen beneath the surface, and this arrested solvent and chemical activity. If the modest figure of 5 per cent. be assigned for this supplementary effect, 20 per cent. of the functional area would be withdrawn from action. Whether this numerical estimate be correct or not, it may be assumed that if a given amount

of withdrawal, combined with associated agencies, were not sufficient to arrest the progress of glaciation, the glaciation would have continued to extend itself until the point of balance was reached. It is, perhaps, not too much to assume that the extension of glaciation and its concurrent agencies mark in themselves the measure of preponderance of the depleting agencies at the stage when glaciation began. That is to say, after the depleting agencies had brought the air's carbonic content down to the point at which the glacial centers were inaugurated, these agencies were still preponderant over the repleting agencies to some such extent as 20 per cent., more or less.

While it does not seem necessary to our general purposes to consider the associated agencies of arrest, if these views be correct, they possess an interest of their own, and may be mentioned briefly.

With little doubt the lowering of the temperature lessened the rate of decomposition of the silicates, though frost action aided in disaggregating them mechanically and in thus increasing the atmospheric contact. On the other hand, while the authorities are not altogether agreed, the weight of the latest opinion supports the view that the limestones would be dissolved by cold water saturated with carbon dioxide faster than by warm water, other things being equal. The cold waters would quite certainly contain more absorbed carbon dioxide than warm ones. Probably other things were not equal, for the vegetable action and the organic acids probably lent less and less aid as the temperature fell. It is not clear what the balance of these influences combined would be. Whichever way it leaned, it does not seem to have been of decisive moment.

As previously remarked, the progressive removal of carbon dioxide from the air reduced the amount of its action, but not proportionately. While this lessened the depleting action it does not seem to have reached decisive moment, at least not until a late stage in the process of depletion.

Meanwhile, in the ocean, conditions favoring reaction were

gathering force as the result of the processes in action there. The ocean was accumulating carbonates and augmenting their degree of bicarbonation with the increase of cold. Now it is obvious that if the loading of the ocean with carbonates were to proceed to the point of saturation, inorganic processes of precipitation and dissociation would come into play to an extent that must necessarily balance all further accessions of material. It does not appear, however, that there is enough, or even nearly enough, carbon dioxide in the air to bring about a condition of full saturation of the ocean with bicarbonates, even if it were all to take that form, and were to be conveyed completely to the sea. But the movement toward saturation should increase in some degree, probably small, the efficiency of inorganic agencies tending toward precipitation, although it could become notably effective only after prolonged accumulation.

The concentration of carbonates in the ocean was somewhat aided by the removal of water required to form the great ice-sheets. On a rather large estimate of the mass of the ice-sheets, this extraction might possibly reach 5 per cent. of the volume of the ocean.

There would probably be a progressive evolution of lime-secreting life adapted to the cooled waters, and this would increase the rate of carbonic release and contribute to a reversal of action.

None of these subsidiary agencies, nor all combined, seem to have been controlling factors.

It is notable that some of these subsidiary agencies, on both sides, are final in themselves and quite without retroactive possibilities. When once their work was done there was no resilience. It was quite otherwise with the ice mantling and the ocean loading. Far from being final, these contained in themselves the potentialities of reaction and gave vigor to the reaction when it took place.

Agencies that precipitated reaction.—When once the reactive agencies had reversed the relative rates of enrichment and

depletion and there began to be an increase of carbon dioxide in the air, the following influences would coöperate to hasten and intensify the reactive movement.

1. The dissociation of the second equivalent of carbonic acid associated with the carbonates of the ocean would be increased, and as the temperature rose from the diffusion of the freed carbon dioxide into the air this would be still further augmented by its own reactive effects. This is one of those interesting agencies whose effects at once become causes of further like effects.

2. The increased warmth would call forth more lime-secreting life in the ocean, and thus also hasten the freeing of carbon dioxide, and this again would react favorably on itself.

3. The increase of water from melting ice would somewhat extend the shallow-water zone and favor lime-secreting life. If the land were depressed by the load of ice, as some suppose, this would increase the sea area and favor lime-secreting life. With this may be associated the falling of the water level in the high latitudes (to which it had been drawn by the gravitation of the accumulated ice mass) and a corresponding rise of the water level in lower latitudes. Since the lower-latitude life is more abundant than the high-latitude life, and more effective in extracting lime, the shift would involve a gain in lime-secreting potency.

4. The increased decay of organic matter attendant on the warmer temperature would develop carbon dioxide; but over and against this must be set the increased carbon locked up in the augmented living matter. These, as before, are set aside, as perhaps mutually offsetting each other.

5. The increase of temperature arising from the preceding causes would increase the water vapor in the air and thereby add to the thermal capacity of the atmosphere, and this would react favorably upon itself and upon the other agencies favored by high temperature.

Thus the reaction once started would be self-augmenting,

until the fundamental conditions were changed or the reaction was checked by its own ulterior consequences. The sequences may be easily followed. The carbonates of the sea, which had been augmented during the epoch of glaciation were now diminished and limestone was more actively deposited. The ocean, previously fattened in carbonates now became lean. So also the carbonates themselves, that before were quite plump bicarbonates, now became degraded to a mixture of normal and acid carbonates. In short, the ocean holds less free and feebly-combined carbon dioxide and the air holds relatively more. As the ocean is now estimated to contain from eighteen to twenty-five equivalents of atmospheric carbonic acid in the free and feebly-combined states, a moderate fluctuation in its content would cover the full range of atmospheric variation required to produce the climates under discussion, according to Arrhenius. On the supposition that the glacial epoch was produced by a reduction of the carbonic content of the atmosphere to one half the present amount, it would only be necessary for the ocean to release 2 or 3 per cent. of its releasable carbon dioxide to restore the atmosphere to the present condition. If the ocean gave up 4 or 5 per cent. of its releaseable carbon dioxide the climate would be notably milder and more equable than the present. Assuming the correctness of Dr. Arrhenius' conclusions, it would seem from these considerations that there is nothing forced or violent in the supposition that an effective interglacial epoch might be brought about by the reactive agencies indicated.

Recrudescence of glaciation.—If the land area of the globe as a whole remained large and high notwithstanding such local depressions as have been attributed to the weight of the ice and the effects of low temperature; or, more precisely, if the atmospheric contact area remained large, the conditions for a renewal of glaciation would again prevail because the renewal of warm temperature, the enrichment of the atmosphere, and the depletion of the ocean would restore the original action. So soon as the ice had retreated from the land, the weathering of the

uncovered area would be renewed. This, of course, would begin so soon as the retreat began, and increase in a corresponding measure; but it is a slow process, while the reactions of the ocean are relatively rapid — indeed they should keep close pace with the rise of temperature which they induce. There should be no appreciable lag. After the retreat of the ice a new surficial factor would come into play, the sheet of drift spread over the surface. In so far as this consisted of undecomposable matter blanketing decomposable matter, it would interfere with the progress of decomposition, but in so far as it consisted of limestones and silicates ground to a flour and exposed to the atmosphere, it would facilitate chemical action and expedite a second depletion of the atmosphere and through it a second term of glaciation. Aside from the effects of this mantle of drift and such changes of topography as might have occurred, the conditions for the renewal of glaciation would be, so far as I see, as effective as they were at the outset. Assuming that they were equal to the preceding, a second glaciation equal to the first is to be postulated, and a corresponding reaction at length, as in the previous case, due to like agencies. Thus a series of glaciations and deglaciations should follow each other until the general causes lying back of glaciation had disappeared.

In so far as the land, on the whole, settled back toward sea level or was worn away, or, by any other agency, lost its degree of effective exposure to the atmospheric action, in so far the conditions of glaciation would disappear. Pursuing the normal history which follows a period of great land elevation, it is to be presumed that there would be a gradual reduction of the land surface and land elevation, and that hence the conditions productive of glaciation would gradually pass away. On such an assumption it is presumed that the recurrent glacial advances and retreats would become more and more feeble until the series vanished. Nominally, then, the glacial and interglacial epochs should form a rhythmical series declining from large oscillations at the maximum to lesser and lesser oscillations as the series

disappeared. This seems to correspond with the observed oscillation of glaciation in both Europe and America.[1]

INTERCURRENT AGENCIES

Without question the normal series of glacial oscillations just postulated would be subject to intercurrent influences which would be liable to disturb, perhaps quite seriously, its regularity and symmetry.

1. Any notable movement in the land which affected the sum total of the atmospheric contact area would disturb the symmetry of the series.

2. Any notable change in the original supply of carbonic acid through volcanic action or other agency would produce obvious modifications. The deformation of the body of the earth out of which the conditions of glaciation are assumed to have sprung would doubtless be favorable to volcanic action, and if this reached a degree of intensity sufficient to add appreciably to the carbon dioxide of the atmosphere, it would radically affect the ongoing of the process. That there was extensive vulcanism nearly or quite concurrent with glacial action has been urged by some geologists; indeed, glaciation has even been attributed to volcanic action.

3. The precession of the equinoxes has been regarded by many thoughtful students of glaciation as an influential agency. If affective, it would superpose a rhythm of its own upon the rhythm postulated by this atmospheric hypothesis. For specific illustration the extensive series of moraines which marked the later stages of the Wisconsin epoch of glaciation are referred by Taylor to precessional influence, while the Wisconsin glaciation itself would, under the atmospheric hypothesis, be referable to atmospheric depletion. The most serious question which here arises is the compatability of the prolonged period implied by Taylor's interpretation with the rate of reaction implied by the

[1] The Classification of European Glacial Deposits, JOUR. GEOL., Vol. III, No. 3, pp. 241–269, JAMES GEIKIE; The Classification of American Glacial Deposits, *ibid.*, pp. 270–277, T. C. CHAMBERLIN; editorial, *ibid.*, Vol. IV, No. 7, October–November 1896, pp. 873–876.

atmospheric hypothesis.[1] This will be more evident as we touch on the time rates.

4. The change in the eccentricity of the earth's orbit which Croll has made the foundation of his beautiful hypothesis of glaciation, if not found competent to produce general glaciation itself, might still be effective in producing climatic changes of less degree, and might superpose important modifications upon the series postulated by the atmospheric hypothesis. It may be remarked in passing, however, that the computed variations of eccentricity of distant periods of the past do not rest on so firm a mathematical basis as is currently supposed.

It is obvious that these and other possible agencies might work concurrently with the atmospheric influences, or antagonistic to them, in either case distorting and masking the normal rhythmical expression which a purely atmospheric series would assume.

DO THE TIME RATES FALL WITHIN WORKABLE LIMITS?

The working capabilities of a glacial hypothesis are somewhat severely conditioned by its time factors. It must not only present a satisfactory correlation between the time of occurrence of glaciation and that of the assigned cause, but the rhythmical action of the cause must be consonant with the rhythmical history of glaciation. That the Pleistocene glaciation followed the Ozarkian or Sierrian stage of elevation at an appreciable distance, I hold to be demonstrated by the relations of the glacial deposits to the eroded topography of that period. On the other hand, there is no evidence of a prolonged interval, geologically speaking. The atmospheric hypothesis demands that the accelerated erosion due to elevation (or rather to the dissection that followed elevation) should have continued long enough to remove about three times the present atmospheric content of carbon dioxide before glaciation could begin, following Arrhenius' computations. This removal could only be accomplished by the *excess* of consumption of carbon dioxide over supply and there is

[1] See GILBERT'S review in last number of this JOURNAL, p. 621.

reason to believe that the rate of supply from the interior was greater than the average on account of crustal disruption and volcanic action. There seems, therefore, little ground to think that the glaciation should have followed closer after the elevation than it seems to have done. It would seem rather that the hypothesis was happy in this time relation at least.

With most geologists, I doubt not, the chief question will be whether the postulated agencies could cause the glacial oscillations, involving the removal and reproduction of the ice, in large part or in whole, as rapidly as the field evidence requires. Present measures of glacial rates and times are quite uncertain but not indefinitely so. Some rude approach to their value may be attained. Recently expressed opinions regarding the time since the last ice retired from the site of Niagara River, and inaugurated the erosion of its gorge, lie between 7000 and 33,000 years, which we may average at 20,000 years. I place no special confidence in this figure, but it is rudely representative of the average order of magnitude of expressed opinion. This represents only a part of the time since the beginning of the deglaciation that removed the Wisconsin ice-sheet. According to Taylor's views it would be only a very small part. I doubt if any careful geomorphic geologist familiar with all the phenomena involved would seriously consider an estimate that made it much more than one half at the most; so that it would apparently not be straining the evidence to take 40,000 years as a rude measure of the time since the beginning of the retreat from the outermost moraine of the Wisconsin stage. However, this may probably be cut in half and halved again without over-straining the possibilities of the hypothesis.

This is the time of retreat. An interglacial epoch involves not only the time of retreat, but the time of interglacial mildness and the time of re-advance. The best specific data now available in America for estimating these elements are undoubtedly those afforded by the excavations about Toronto which have

been so fruitfully cultivated by Hinde, Coleman, and others.[1] (1) The time occupied in the ice retreat is there almost without record. (2) The duration of the mild climate is recorded in thirty-five feet of clays and sands. It is also implied in the time necessary for the migration of the Paw Paw, Osage Orange and other trees from more southerly regions to this rather northern locality, and also for the migration of the clams and other molluscs from the Mississippi waters to this rather distant region. Both of these migrations were probably rather slow processes. (3) The initiation of the returning cold is recorded in 150 feet of fine stratified peaty clays and sands. (4) Following this there was an unknown period occupied in the transition from the conditions of deposition, during which the preceding series had been formed, to the conditions of effective erosion which followed. To suppose that this transition was due to the removal of an ice-dam that had lingered in the lower St. Lawrence seems quite untenable for a long, mild period and a long, cool, but not glacial, period had intervened. It was probably due to the cutting down of the drainage outlet, or to a surface movement, or the two combined, and hence probably occupied an appreciable time. (5) There then followed a period of erosion comparable to that since the last ice invasion. Succeeding this came the re-invasion of the ice-sheet.[2] These data seem to fairly imply that the interglacial epoch represented at Toronto was several times as long as the postglacial epoch.

While nowhere else has so complete a record been found, many estimates of the differences of erosion of the several till sheets in the Mississippi valley, where the formations are well deployed and happily suited to such studies, have been made

[1] GEORGE JENNINGS HINDE: Glacial and Inter-Glacial Stages of Scarborough Heights. Can. Jour. 1878, p. 388 *et seq.*

A. P. COLEMAN: Am. Geol., Vol. XIII., February 1894, pp. 85–95. Ditto. JOUR. GEOL., Vol. III., No. 6, 1895, pp. 622–645.

[2] Canadian Pleistocene Flora and Fauna: Report of the Committee consisting of Sir J. W. Dawson (chairman), Professor D. P. Penhallow, Dr. H. M. Ami, Mr. G. W. Lamplugh and Professor A. P. Coleman (secretary), appointed to further investigate the flora and fauna of the Pleistocene beds in Canada.

by experienced glacialists, and their concurrent judgment is that the least of the notable interglacial intervals was at least two or three times as great as the postglacial interval. It would not be exceeding current judgment, therefore, to assign from 80,000 to 120,000 years as the duration of a typical interglacial epoch.

But in the interest of conservatism let the postglacial interval be taken at 10,000 years and the interglacial at 20,000 or 30,000 years. This seems to me excessively conservative. If the assigned agencies can affect a reënrichment of the atmosphere in carbon dioxide to an amount somewhat exceeding the present content and then again a depletion of one half within 20,000 or 30,000 years, the hypothesis will not be excluded by time limitations.

We have the following pertinent data based in part on Reade's[1] estimates of the present rate of removal of carbonates:

Total mass of the atmosphere	5×10^{15} tons
Mass of atmospheric CO_2 (reckoned by weight at .0006)	3×10^{12} tons
Total mass of CO_2 taken annually from the atmosphere	162×10^{7} tons
Mass of CO_2 consumed annually in original carbonation (reckoned by area at 20 per cent. of the land)	27×10^{7} tons
If reduced one half on account of the slower rate of decomposition of crystallines it will be 13.5×10^{7} tons, in which case the other half is to be added to the following item, if Reade's estimates are correct.)	
Mass of CO_2 consumed annually in forming bicarbonates	135×10^{7} tons
Time required at this rate to consume total atmospheric CO_2, assuming no return	1852 years
Time required at this rate, without return, to consume one half atmospheric CO_2 (the reduction requisite for glaciation.)	926 years
Time required to consume half the "free" and "loose" CO_2 of the ocean (estimated at 18 times that of the atmosphere) without return	16,668 years
Time required to consume half the CO_2 of the atmosphere and the ocean combined, without return	17,594 years

The last items which involve the reduction of the carbon dioxide in the ocean as well as in the atmosphere are not really

[1] Loc cit. on p. 569.

pertinent to the discussion, if the foregoing doctrine relative to the mode of action of the ocean during a glacial period is correct, for it is there maintained that the ocean does not give up its carbonic acid with increasing depletion of the atmosphere, but, on the contrary, increases its content. They have some interest, however, in connection with it and with other phases of the atmospheric hypothesis which the reader may possibly wish to consider. They also have some pertinency to the discussion of Paleozoic glaciation, to be taken up presently.

We are here concerned especially with the rate at which atmospheric carbonic acid may be consumed to the amount of one half the total content. For convenience, no account has been taken of the return of carbonic acid from the ocean or through organic action. We reach the rather startling result that if there were no return, the decomposing and solvent action on the present contact area would consume one half of the atmospheric carbon dioxide in less than 1000 years. This result, based on Reade's estimate, may be checked by independent computation on a more familiar basis and by different modes of computation. For example, by assuming the average rate of degradation of the land surface to be one foot in 5000 years, and that the carbonates constitute 15 per cent. of the material removed, one half of the carbonic acid of the atmosphere would be consumed in 1248 years, if there were no return; or in 1000 years if the degradation was one foot in 4000 years.

The actual depletion must, of course, depend upon the excess of this rate of removal over the rate of return. I have already endeavored to show that there was a very large fluctuation in the conditions that determined the relative rates of consumption and return, notably that the land of the Ozarkian time was more than 20 per cent. greater in area than the present land, and that its elevation was probably 100 per cent. or 200 per cent. greater at the maximum stage of protrusion. And this was correlated with coöperating conditions in the ocean. Both of these estimates, however, must be considerably reduced to give a safe measure of the area which was operative at the time of the

inter-glacial epochs, or at least some of them, for there is abundant evidence that the land was not then so greatly elevated as in the Ozarkian or Sierrian period.

Instead, therefore, of combining 20 per cent. increase of land area with 100 per cent. increase of elevation, and these with the coöperating 20 per cent. reduction of sea area, the destruction of sea-shelves, and the restraining effects of lowering temperatures, as we are entitled to in bringing down the rich Tertiary atmosphere to the lean conditions of the glacial period, let us content ourselves with some modest fraction of these intensifying combinations. If we only assume that the agencies of depletion were superior to the agencies of return by the amount of 10 per cent., the depletion requisite to bring on a glacial epoch, starting with atmospheric conditions like those of the present, would be effected in less than 10,000 years. If, therefore, we over-generously allow as much time for deglaciation as for reglaciation, an interglacial epoch might not require the operation of the postulated agencies for more than 20,000 years, so far as they themselves are concerned. The development of the ice-sheet might take more time, but we have little or no data for estimating this. If 10,000 years additional is allowed for this the total remains at the modest figure of 30,000 years.

It would not seem to be pushing the data previously given to extremes to postulate a larger percentage of difference between depleting and repleting agencies than 10 per cent., which would make the requisite atmospheric depletion possible in a shorter period. It is probably not extravagant to assume that the difference might rise to 20 per cent., in which case the requisite time would be brought down to extremely modest limits. It is difficult to see how anyone who studiously considers the phenomena of the Toronto interglacial epoch could assign to it a duration less than is compatible with these agencies, as here interpreted. It would seem, therefore, that the hypothesis is not excluded from the working category by inadaptibility to the time rates of the phenomena which it seeks to elucidate.

There is not likely to be any serious question respecting the

time rates at the other extreme, that is, that the agencies necessarily act too rapidly to correspond to the phenomena. Of course, in the final adjudication of the hypothesis, it will be necessary to show that its time rates not only might correspond to the time rates of the phenomena, but that they did so, but this is a labor of the future, and is obviously dependent upon a very notable extension of precise knowledge, which it is the purpose of the hypothesis to aid in calling forth. It is sufficient here to show that reasonable postulates, based on a reasonable estimate of the phenomena, fall within compatible limits.

T. C. CHAMBERLIN.

(To be continued.)

THE NAMING OF ROCKS

Introduction of new names.—In the early days of petrography it was supposed that there existed rock types as definite as mineral types. Following this hypothesis, a rock found which was different from any rock before described was immediately given a new name. This went so far that an altered rock was given a family name, as in the case of *diabase*, an altered dolerite. After some years a scheme of nomenclature was worked out which was supposed to be approximately complete. For a time subsequently, when a rock was discovered having a somewhat different character from previously known rocks, it was referred with modifying mineralogical prefixes to some of the so-called types.

A few years ago another period of name-giving was inaugurated. During this period, which continues to the present time, petrographers have introduced numerous new, independent names, both for long-known and for newly-discovered varieties of rocks. Since 1890 more than fifty new names have been added to the nomenclature of the igneous rocks, a larger number than young petrographers were obliged to know the meaning of before 1890. The stage through which petrography is passing is somewhat similar to that through which at one time paleontology passed. One might almost think that petrographers were seeking to find varieties of rock slightly different from those before known in order to give them new names.

Method in giving new names.—The method of petrographers in proposing names, so far as any method is discoverable, is to give an independent name to each rock which is slightly different from any previous rock found, without reference to any definite plan of nomenclature. The greater number of the names are not proposed to designate varieties which are subordinate to previously recognized kinds of rocks, but are names coördinate with those before used. In petrography, a binomial nomenclature thus far has not been generally adopted, and therefore it has

not been possible to drop the new name and place the thing referred to under a larger division, as one may drop the specific name of a new fossil and speak only of the genus to which it belongs. Furthermore, the new names of petrography are in most cases unlike most of those in biology or in mineralogy, in that the things described and given names have no clearly distinguishable characteristics by which they may be recognized. As a result of this inherent vagueness, it is very difficult indeed, from the descriptions published, to obtain a clear conception of what is meant by many of the new petrographical names. Indeed, it may be doubted whether many professional petrographers, to say nothing of those who work in other lines of geology, have a definite conception of the meaning of many of the fifty or more names which have been proposed since 1890.

Principle underlying naming of rocks.—In giving numerous new names to rocks, while no principle is announced by the petrographers, the underlying assumption is the same as that which prevailed in the early days of petrography; that is, rocks may be divided into definite types, which are comparable to definite mineral or animal species. I do not for a moment suppose that petrographers who have introduced these new names would state that they believe this principle. I merely assert that many of the numerous names are justified only if the principle be true.

Responsibility of introducing new names.—The petrographer who introduces a new name for a rock assumes a responsibility which ought to be incurred only after the most careful consideration. Probably some of the new names which have been recently introduced were necessary to the progress of the science. That many of them were not, I venture to believe. One who introduces a new name without the best of reasons for so doing is hindering the advance of the science of petrography, as well as occasioning loss of time and great inconvenience to his fellow workers.

Statement of the problem.—All philosophical petrographers now understand that between all kinds of rocks there are gradations—from basic to acid, from coarsely granitic to glassy, from rich sodium

rocks to rich potassium rocks, from massive lavas to tuffaceous forms, from the freshest rocks to the most altered, from the oldest rocks to the newest, from the igneous to the aqueous rocks; between all of the various forms of the sedimentary rocks. Moreover, many of the important stages of these gradations have been noted. Still further, in one region the gradation from one kind of rock is in one direction, and in another region is in a different direction. For instance, here a granite grades into a diorite; there grades into a syenite.

What shall be the criteria for naming rocks?—These being the facts, the question arises, what is the most important consideration which shall determine whether or not a certain kind of rock shall be assigned a name. It appears to me clear that the most important consideration is *the relative abundance of the rocks.* We must have names for the common things. It is well known that certain of the multifarious kinds of rocks which have been named are more abundant than others. Probably the igneous rocks, which can be included under twenty names, comprise nine tenths or more of the mass of the igneous rocks. It follows that a philosophical method of rock nomenclature involves a knowledge of the relative abundance of the different kinds of rocks.

However, it is not meant to imply that abundance shall be the only consideration in the naming of rocks, but merely that it shall be a fundamental one. While abundance ought to be the first consideration, this idea must not be pushed to an extreme. All rocks which must be assigned names will not be found in equal abundance. Some rocks which do not have specific names assigned to them may be more abundant than some other rocks deserving of a name. For instance, olivine-gabbro may be more abundant than some of the leucite rocks to which names must be assigned. This but illustrates the well-known principle that great variations due to secondary factors shall have weight in proportion to their range, and that therefore they may have an important modifying influence upon the application of the primary considerations.

Influence of rock classification on naming of rocks.—The broad question of rock classification I do not intend here to discuss. However, it is necessary to mention some of the criteria which are recognized in the classification of rocks, since these are also factors in the naming of rocks. By most petrographers, chemical composition, mineral constituents, and rock textures and structures are controlling considerations; but by different petrographers these are placed in different orders of importance. By some petrographers the distinction between plutonic and volcanic rocks is given weight in classification. In making a classification of rocks it is necessary to consider to what extent the altered rocks shall be recognized, and whether such textural terms as porphyry and obsidian shall be used in naming rock species. Doubtless different petrographers would decide these points in various ways.

Now the above factors, which are controlling considerations in the classification of rocks, are of necessity secondary factors in the naming of rocks. If a new rock be found, which, in regard to these secondary factors, is so different from any previously known rocks that it cannot be grouped with any of them by the plan given below, it may be entitled to a new family name, even if not abundant.

But to return to the matter of abundance. After a system of classification shall have been worked out by a petrographer, he must decide what rocks shall have independent names. It is my contention that at this point abundance shall be recognized as having the place of first importance. Names are tools by which we avoid the circumlocutions of descriptions. Since, as already shown, there are everywhere gradations between rocks, not every phase of rock can have an independent name, else the number of names would be infinite. Since every rock phase cannot be assigned a name, what kinds shall be selected for such names? Manifestly those which occur most abundantly. For the common things, the common kinds of rocks, as a matter of convenience, I repeat, we must have names.

As above noted, it has been supposed that a rock might be

designated as a type which has certain characteristics. However, the only method of nomenclature which is logical is that which takes into account the fact of gradation and stages between all rock varieties; that types exist only as descriptions or specimens selected by man, not by nature; but abundance is determined by nature. All this is recognized in the scheme given. The definite forms which are selected for names are those which are abundant. This applies as well to the original forms of rocks as to their altered varieties. Had the varieties of rocks intermediate between those abundant kinds which have been given names been the abundant ones, rather than those to which names have been assigned, these would have been the rocks which should have been given names, and which in all probability *would have been given names* during the first period of the development of the science of petrography.

How shall demands for exactness be met?—But the question now arises as to how the demands of the petrographers for exactness shall be met without introducing a new independent name the moment a slightly different variety of rock is discovered, however small its mass. This demand may be met by the general application of special usages below given. The majority of the abundant kinds of rocks were early assigned names. To less abundant kinds of rocks intermediate between the more abundant kinds, names compounded from the simple names may be used; for example, granodiorite, trachydolerite, trachyandesite.[1] To either the simple or the compound names may be prefixed mineralogical qualifiers, thus further compounding them; for example, quartz-diorite, olivine-gabbro, analcite-basalt, augite-trachydolerite. With these simple or compound names, geographical qualifiers may be used. If the rock is so abundant and definite as to require a specific name, the geographical qualifier may be compounded with the more general name, as Hellefors-diabase. If, however, the idea is exactly to designate the rock occurring at a particular locality, without implying that

[1] Italian petrographical sketches, V, by H S. WASHINGTON: JOUR. GEOL., Vol. V, 1897, pp. 365, 366.

it is so abundant and important as to require a name to enter rock nomenclature, the geographical name may be used simply as a qualifier, as, Duluth olivine-gabbro. This usage gives the most exact discrimination without cumbering nomenclature with a multitude of independent names. In any of the foregoing classes of names the prefixes meta, apo, epi, schisto, gneisso, or other terms may be inserted for the altered rocks.[1]

Under the plan proposed we shall have coördinate simple names of about the value which Rosenbusch has designated as family for rocks which are the most abundant and important. We shall have compound names for rocks intermediate between the more abundant kinds. We shall have names with geological qualifiers, either compounded or not, as the case demands, for a further refinement in discrimination. In any of these three classes of names mineralogical qualifiers may be introduced as an additional discrimination. For all of the previous classes we shall have prefixes, with definite meanings, for the altered equivalents of the different rocks.

The method proposed is practically that of a binomial or trinomial nomenclature. The fundamental names would be based primarily upon abundance, and secondarily upon other factors. The secondary names would be introduced under the same principles.

Application of plan proposed.— How this plan can be worked out may be illustrated by some cases from recently described rocks. (1) *Nordmarkite*,[2] by Washington, is placed as equivalent to *mica-hornblende-quartz-syenite*. The rock is therefore a syenite. Assuming that this rock is sufficiently abundant so that it should have a place in nomenclature, it may be called *nordmarko-syenite*. In the same way, *akerite*[3] (augitic quartz-syenite) may be called

[1] In another place (Metamorphism, Monograph, U. S. Geol. Surv.) I shall discuss in detail the use of these terms. But in the present paper I do not wish to take up the subject. Here I wish merely to suggest a method of handling the altered rocks, rather than to discuss the details of its application.

[2] The petrographic province of Essex county, by H. S. WASHINGTON: JOUR. GEOL., Vol. VI, 1898, p. 799.

[3] JOUR. GEOL., Vol. VI, p. 796.

akero-syenite, if a new name is really necessary and preferable to augitic quartz-syenite. (2) The trachydolerites, designated by Washington as *ciminite*, *vulsinite*, and *toscanite*,[1] may be called *cimino-trachydolerite*, *vulsino-trachydolerite*, and *toscano-trachydolerite*. Under this usage *cimino*, *vulsino*, and *toscano*, take the same place with reference to the trachydolerites, that *hellefors*, *aasby*, *särna*, *ottfjälls* do to the diabases, as used by Rosenbusch (see p. ——). Indeed, Washington himself in one place speaks of *pulaskite* as *pulaskitic syenite*.[2] Following the plan proposed this would be *pulasko-syenite*. (3) As an illustration of the use of mineralogical terms compounded with names already compounded may be given *augite-toscano-trachydolerite*. If desirable, the order of the mineralogical and geographical parts of the name may be reversed. For instance, the leucite-trachytes, which Cross calls *orendite* and *madupite*,[3] may be designated *orendo-leucite-trachyte* and *madupo-leucite-trachyte*.

In all of these cases the geologist knows at once the general character of the rocks referred to. In the first case he knows the rocks are syenites; and, furthermore, that certain varieties of syenites are so abundant and so definite in character as to require a specific designation. In the second case he knows that there is a kind of rock intermediate between the trachytes and dolerites, and, if he knows what trachytes and dolerites are, he has a very clear conception of this rock without any further definition. He further knows that there are variations in the character of the trachydolerites which occur at particular localities, and which, in the opinion of the author, are so abundant and distinctive as to require specific designations. In the third case he further knows at once from the name that certain varieties of the Toscano-trachydolerite contain augite; and infers that this variety is exceptional. He knows that the leucite-trachytes have variations which are thought to be of sufficient importance to require specific designation.

[1] Jour. Geol., Vol. V, pp. 350–361.

[2] Jour. Geol., Vol. VI. p. 804.

[3] Igneous rocks of the Leucite Hills and Pilot Butte, Wyo., by Whitman Cross: Am. Jour. Sci., Vol. IV, 1897, pp. 138, 139.

It is also self-evident that the extreme refinement practiced by Washington and Cross is in no respect lost by using the nomenclature proposed, rather than assigning independent names to particular varieties of rocks described. Indeed, the compound names proposed give additional refinement to that attained by independent names.

In giving the above illustrations I express no opinion as to whether the various syenites, trachydolerites, and leucite-trachytes are so abundant and important as to be worthy of specific names. This is a matter for the petrographer to settle. I merely use these terms as convenient illustrations as to how rock nomenclature can be handled so as to serve the purposes of the general geologist and the specialist, without throwing the subject of petrography into hopeless confusion.

Objection to long names.—The long terms resulting from the plan, as, for instance, augite-toscano-trachydolerite, may be objected to on account of their cumbersomeness and complexity. However, it may be said that these names are simple as compared with many of the names used in organic chemistry, and furthermore that they are justified on precisely the ground that the long names in organic chemistry are justified, that is, they are intelligible names. This is the fundamental point. The present method of naming rocks is not intelligible even to professional petrographers, and an unintelligible method can no longer be tolerated. The method proposed is intelligible to every geologist, whether a specialist in petrography or not, and gives at once the information desired by the general geologist and the extreme refinement demanded by the petrographer. The plan proposed gives all the advantages of generic, specific, and varietal names. If any petrographer can suggest a method of naming rocks which will better satisfy the demand of the petrographer for exactness, and of the geologist for intelligibility, I shall gladly favor such a plan rather than my own proposal.

Why petrographers have not generally followed plan outlined.—The plan suggested is so simple that the question immediately arises as to why petrographers dealing with igneous rocks have

not followed it. Was there not some good reason for the introduction during the past years of many new, independent names? The answer is, petrographers had not worked out any plan as to the naming of rocks, and to assign a new name for each new variety of rock was the easiest way out of the difficulty, although it was disastrous so far as their fellow workers were concerned. Then the honor of giving a new name to rock nomenclature doubtless had a too important effect. Furthermore, many of the petrographers still held, in a subconscious way, to the old notion of rock types, not yet having grasped the idea of general gradation.

Plan followed in case of sedimentary rocks.—That the scheme proposed is practicable is shown by the sedimentary rocks, where it has been substantially followed, although as a matter of necessity rather than a conscious system. In the sedimentary rocks, from the first, gradations were recognized, and hence the tendency to give each variety a new name never got any headway. To illustrate the application of the scheme to the sedimentary rocks, we may take the sandstones. There is an almost infinite variety of sandstones, but it so happens that petrographers have not been directing their energies to the minute discriminations of their variations, and we have not a dozen or score of different names for the different kinds of sandstone. Yet the sandstones of different localities are discriminated and recognized as different from one another by attaching the names of the localities at which the rocks occur to the name, and thus discriminating each rock from all others. For instance, in Wisconsin a peculiar sandstone occurring locally is called the Madison sandstone. From this designation the general geologist at once knows that this formation has the general characters of the rocks which have been called sandstone, and he will not go further. But if he is interested in the Madison district for some reason, scientific, economic, or otherwise, he may go further and learn the peculiarities of the particular sandstone which is found at Madison.

By this method the sedimentary formations are discriminated

the world over. However numerous the names for the sedimentary rocks may be in the future, the method still must be used, for however fine the discriminations resulting from such names, there will be variations from the meanings assigned to these names, and thus the local names are necessary.

In exceptional cases plan followed with igneous rocks.—The simple method proposed of designating the slightly different varieties of igneous rocks from one another, without throwing their nomenclature into hopeless confusion, has already been followed in several cases.

A notable instance is the term *Andendiorite* proposed by Stelzner[1] for a particular rock which has the general characters of a diorite, but which in some respects differs from ordinary diorite, and occurs in the Andes. A geologist who does not care to go into the detailed petrography of the region notes at once that in the Andes is a rock which has the general characters of the diorites, but which in some respects differs from the ordinary kind. He also at once knows that in the Andes is a rock which is different from the ordinary diorites, but which is allied to them. If in his investigative work he wishes to know exactly the meaning of the modifying term, he can do so by reading Stelzner's paper, or by obtaining specimens and an analysis of the rock. In the case of *Andendiorite*, the name has been also used as a new specific name, an dapplied by Iwasaki[2] to a somewhat similar rock in Japan. To a certain degree this shows how the method may be made to work out in practice in reference to the igneous rocks. When here and there other rocks are discovered similar or almost identical with the Andendiorite, and this variety of rock, as a result of these investigations, is found to be so abundant and so definite in its characters as to demand a specific name, the original word *Andendiorite* may be used for this purpose, or, better, a new specific name may be coined for it, and the rock be placed in the scheme of rock nomenclature.

Rosenbusch has used the method of geographical qualifiers

[1] A. STELZNER: Geologie und Paläontologie, von Argentina, p. 213.

[2] Andendiorite in Japan, by C. IWASAKI: JOUR. GEOL., Vol. V, 1897, pp. 821–824.

in a number o finstances precisely as proposed, for discriminating rocks. For example, he describes *helleforsdiabas*, *aasby-diabas*, *sarnadiabas*, *ottfjallsdiabas*.[1] Had some petrographers described these rocks perhaps we would have had four additional, independent names to remember, the value of which we would know absolutely nothing of, without any suggestion whatever as to the family, in Rosenbusch's sense, to which these new rocks belong.

The method proposed has unconsciously been followed to some extent by the United States Geological Survey. That organization has recognized that a sufficient number of independent names could not and should not be coined to designate every variety of rock. It has practically, if not by definition, recognized the endless variation and gradation throughout rock formations, by providing that *aqueous and metamorphic formations alike* should be given local names; for example, Chicopee-shale, Hoosac-schist, Becket-gneiss, etc.[2] This use of local names has furnished a more accurate method of discrimination than could be afforded by independent names. Moreover, only rocks which are present in some quantity have been given formation names. Thus, by practice at least, the idea of abundance as a factor in the naming of rocks has been recognized.

Suggestion to petrographers who have introduced new names.—In this connection it may be suggested that petrographers who have recently introduced new independent names would perform a service to geologists who are not petrographers, and to many other petrographers, by giving in subsequent papers equivalent names on the basis of the plan above advocated, to the special rocks to which they have given names. If this be done, the relative merits of the two plans will be tested. Within a short time it will be seen whether geologists and petrographers use the independent names or the more general names compounded with geographical and mineralogical terms. Where a new independent name was really needed, and performs a service in the

[1] Mikroskopische physiographie, II, Massige Gesteine, H. ROSENBUSCH; S. 219–220.

[2] Holyoke folio No. 50, Geological Atlas of the United States.

advancement of science, it will be sure to be retained. If it drops out of use, its proposal was premature.

Summary of advantages of proposal.—In conclusion, some of the advantages of the foregoing plan may be summarized:

1. The plan proposed serves all the purposes of nomenclature, from names of a general character to those giving the most minute discriminations. It has the advantage of grouping different varieties of rocks under terms, the general meaning of which is known to all. In the matter of nice discrimination it far surpasses the plan of independent new names for new varieties of rocks. It permits at once any difference in the character of a rock, however slight, to be discriminated, and it permits the growth of petrography by the grouping of the allied varieties together under a new specific name so soon as they shall have been found so abundant, so peculiar, or so important as to demand such a name. The professional petrographer will thus have a much more convenient and elastic nomenclature for describing rocks than he has at present. He may ignore minor differences between rocks in one sentence, and in the next sentence deal with the most refined differences between them. Thus the plan advocated meets both the demands of the geologist and of the specialist in petrography.

2. The plan proposed puts the available information of petrography in such shape that some master mind in the future may reduce the subject to a science. The present scheme of rock nomenclature makes it impossible for any person to get the facts clearly before his mind in such a way that they can be handled. The provisional scheme proposed accomplishes this end. If it be generally followed by petrographers, it is probable that within a few years it will be possible to propose a definite scheme of rock nomenclature, the terms of which correspond roughly to genus, species, and variety in biology.

3. It is believed, if once rock nomenclature be placed upon a reasonable basis, that this will be a great step toward the establishment of a satisfactory scheme of rock classification.

4. Under the plan suggested it will be easy for the student

to get definite notions of the common kinds of rocks. Having this knowledge, he knows without explanation the meaning which is to be attached to a name compounded of two of them. He knows without a moment's reflection the meaning of a mineralogical qualifier prefixed to a noun. He knows that a geographical qualifier means the particular variety of rock which occurs in a certain district. Thus it will be possible for a student to gain a comprehensive knowledge of the chief kinds of rocks at a very early stage of work, and to supplement his general knowledge by details as his work advances.

5. A further advantage of the foregoing plan will be that many of the earliest rock names proposed will be retained, although some may be abandoned. The reason why so many of the old names will be retained under the plan proposed is that many of the abundant rocks were first found; for, as already noted, while the petrographers supposed they were following the plan of naming rocks on the basis of types, they were largely following the plan of naming rocks on the basis of abundance.

6. Still another of the manifest advantages of the plan is that it throws the emphasis on the proper thing; it calls attention to the common, not to the exceptional, rocks. Many petrographers, in discussing the rocks of an area, describe with the utmost particularity the minute characteristics which are peculiar to the exceptional rocks of the district or region, and say comparatively little of the common rocks which compose the great mass of the rocks of the area. Of course, there is some justification for this, in that the characters of the common forms are known. But all papers describing the geology of a region should be so framed as to give a clear conception of the common kinds of rocks which are preponderant, and indicate that the exceptional things described in such detail are only so described because of their peculiarities. To the reader in some way should be conveyed the idea of the relative abundance of the rocks. The error of emphasizing the exceptional and overlooking the common phenomena has been one of the most pernicious mistakes which runs throughout geological papers and text-books. For instance,

many pages in a text-book are given to a discussion of earthquakes, and only a small fraction of that space is given to the vastly more significant, slow earth movements which occur without earthquakes or with earthquakes as secondary phenomena.

7. Finally, the foregoing plan has one further advantage. It emphasizes a great law of nature, the law of gradation — the principle that ultimately there is no such thing as an absolute type. In this respect, petrography, if it will but use its opportunity, has an advantage over any other subject. In biology there have once been gradations between species, between families, between classes. Many of these gradations have been destroyed in the course of evolutionary processes. However, in petrography all of the gradations yet persist, and thus it furnishes the best illustration of the principle of gradation, a fundamental principle of nature.

C. R. Van Hise.

Madison, Wis.,
November 1899.

EDITORIAL

A PROPOSED INTERNATIONAL JOURNAL OF PETROLOGY.—The committee appointed by the Seventh International Congress of Geologists to consider plans for the establishment of an International Journal of Petrology has chosen Professor F. Becke of Vienna, well known as the editor of *Tschermak's Mittheilungen*, President of the Committee, and has taken the first steps toward the organization of such a journal. It has been proposed that articles appearing in it shall be printed in French, German, or English at the option of the author.

While primarily intended for the publication of reviews and abstracts of all petrographical papers wherever published, it is suggested that it may include also articles which shall appear in it for the first time. The carrying out of this must depend upon the financial support the journal receives.

The journal is to be managed by a committee appointed by the International Congress of Geologists, the committee to select an editor who shall have two assistants; the editor and assistants to receive salaries for their services.

The desirability of having one source, thoroughly up to date, to which to turn for information concerning all matters published on petrology is self-evident to all attempting to keep abreast with the rapid advance of this science. One has only to observe what a great impulse to the science of mineralogy has been given by the establishment of Groth's *Zeitschrift für Krystallographie*, to be convinced of the usefulness and convenience of such a journal.

The necessity of forecasting as correctly as possible the financial support obtainable for such a journal has suggested to the American members of the committee the plan of calling attention to the enterprise and of inviting all interested in its success to communicate to either of them such suggestions or information as may aid in estimating the amount of annual

subscriptions or contributions that may be obtained from this country.

It is expected that the chief support will come from individual subscriptions and from university and public libraries, but it may be possible to obtain assistance, in the first years of the undertaking at least, from other sources.

J. P. IDDINGS,
L. V. PIRSSON,
Members of the Committee for America.

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DO STATE SURVEYS PAY? The question has often been asked, and in the coming legislative season probably will be asked many times. An answer is usually desired which deals with dollars and cents, but, perhaps, a partial answer may be given by noting the sort of requests for miscellaneous information which consume a not unimportant portion of the time of survey officers.

For illustration, the requests of a single day in the office of one of the smaller surveys may be noted. Two came in the morning mail. The first was from a professor in one of the smaller colleges, asking for twenty copies of a certain pamphlet to use in the class room. The second was from a consulting chemist, retained by some eastern capitalist to investigate the advisability of establishing an important manufacturing plant in the state. He wished to know the amount, quality, and average cost of certain ores which were being mined there, and the probability of larger quantities being mined. A third request was made in person, by the engineer in charge of locating an important line of railway. He wished a report upon the mineral resources of all kinds along the proposed line. A fourth request came in the afternoon mail. It was from a high-school teacher, who wished for a certain report to use in teaching. The last request was from a reporter, sent to secure an interview relative to certain reputed iron deposits that the local papers of a certain section of the state were making much of. The city editor of a big daily wished to know whether there was any iron there. If so, how much. What was its quality, and what the chances of securing its development if proper publicity were given the matter. He wanted "facts which could be relied on," and so he sent to the survey.

All these requests were attended to in detail, and the tired official wondered when he was to get time to write, revise, and print the report on the year's field work.

H. F. B.

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.[1]

DAVIS,[2] in connection with an account of the Triassic formation of Connecticut, maps the boundary between the Triassic and crystalline rocks to the east and west. The prevailing monoclinal faulted structure in the Triassic involves a similar structure in the crystallines below, and it is believed that the structure observed in the Triassic is due to the slipping of large slabs of the crystalline rocks and the overlying Triassic rocks, in such way that each slab was elevated with reference to the slab next to the west, or, lowered with reference to the one next to the east. The explanation of the cause of the faulted structure is the same as that offered in a previous paper.[3]

Merrill[4] gives a general account of the geology of the crystalline rocks of southeastern New York.

The crystalline rocks lie on the east of the Hudson River, in New York, Westchester, Putnam, and Dutchess counties, whence they extend into Connecticut; and on the west of the river, in Orange and Rockland counties, whence they extend southwesterly into New Jersey. The lowest member is a coarse hornblende-granite which forms the central mass of the range of mountains known as the Highlands of the Hudson, and, in their highest peak, Breakneck Mountain, is exposed through a vertical height of nearly 1200 feet. Other granites, nearly free from hornblende, occur in subordinate masses. The granites are probably igneous and of great age. On their flanks are banded gneisses, the Fordham Gneiss, consisting chiefly of quartz and orthoclase, with biotite and hornblende, and containing numerous beds of magnetic iron-ore. The gneisses on the south side of the Highlands extend through Westchester county in a series of folds with southwesterly trend, and on the northern slope of the Highlands, at several

[1] Continued from p. 425, Vol. VII, JOUR. GEOL.

[2] The Triassic formation of Connecticut, by WM. M. DAVIS: Eighteenth Ann. Rept. U. S. Geol. Surv., Part II, 1898, pp. 1–192. With geological map.

[3] The Structure of the Triassic Formation of the Connecticut Valley, by WM. MORRIS DAVIS: Seventh Ann. Rept. U. S. Geol. Survey, 1888.

[4] The geology of the crystalline rocks of southeastern New York, by F. J. H. MERRILL: Report of the New York State Museum, 1896, pp. 21–44.

places in Dutchess county, are overlain unconformably by quartzites, which are believed to be of Cambrian age.

Ries[1] describes the geology of Orange county, New York. Pre-Cambrian rocks form the Highland region in the eastern part of the county, the northwestern side of Bellvale Mountain, and a series of rounded knob-like hills extending from Sugar Loaf village to Newburgh. They comprise gneiss, at times massive and resembling granite and limestone. The crystalline rocks are folded and faulted, the folds plunging frequently to the northeast.

In the south-central part of the county is found an area of white and blue limestone, which continues south into New Jersey. The white limestone is found in New Jersey to contain fossils of Cambrian age. Exposures are found east of the road, 1¼ miles west-southwest of Pine Island station, which show the passage of the blue into the white limestone. Other, similar areas of limestone are found to the northeast.

Limestones interbedded with the gneisses are found at Popolopen Pond, and again at Fort Montgomery.

Wolff and Brooks[2] present a final discussion of the age of the Franklin white limestone, of Sussex County, N. J. The pre-Cambrian age of the white limestone is believed to be shown by the following facts:

The supposed cases of interbedding of the white limestone and the Cambrian quartzite are found to be due to faulting, or to peculiar conditions of deposition. On the other hand, while it is difficult to prove that the white limestone and pre-Cambrian gneiss are actually interbedded, narrow bands of the true gneiss do occur within the white limestone belt, and seem to be an integral part of the series.

The granite occurring in the area is intrusive in the white limestone, and the nature of the contacts of the granite and the Cambrian quartzite indicates that the intrusion was prior to the deposition of the Cambrian quartzite and blue limestone. While the intrusion of the granite has caused local metamorphism of the white limestone, it is believed that the crystallization of the limestone antedated the granitic intrusion, and was contemporaneous with the crystallization of the gneisses in their present form.

[1] Geology of Orange county, by HEINRICH RIES: Forty-ninth Ann. Rept. of N. Y. State Museum, for 1895, Vol. II, 1898, pp. 395–475. With geological map.

[2] The age of the Franklin White limestone of Sussex County, N. J., by J. E. WOLFF and A. H. BROOKS: Eighteenth Ann. Rept. U. S. Geol. Surv., Part II, 1898, pp. 425–457. With geological map.

The structural relations of the three belts of Cambrian blue limestone with the gneiss and white limestone are such as to indicate unconformity. Along the normal contacts of the blue and white limestone the quartzite intervenes between the two. The bedding of the blue limestone and underlying quartzite is everywhere conformable, while the dip of the foliation of the white limestone and the gneisses is discordant with this bedding.

Isolated patches of Cambrian quartzite are found within the white limestone area. In one place a crevice in the white limestone is filled with the Cambrian quartzite containing undoubted pebbles of the white limestone.

Comment.—The results above presented bear evidence of close and careful field study. The pre-Cambrian age of the white limestone is clearly proven, thus satisfactorily disposing of a much disputed question.

There now remains the question of the origin of the gneisses. In this connection attention may again be called to the marked similarity of the limestones and associated gneisses of the New Jersey area, to the pre-Cambrian limestones and associated gneisses of the Adirondack and Original Laurentian districts to the north. In a general way it would seem that the story worked out for one of the districts may perhaps apply to the others.

Weidman[1] describes the pre-Cambrian igneous rocks of the Utley, Berlin, and Waushara areas, in the Fox River Valley of Wisconsin. They range from volcanic flows to masses of deep-seated origin, with corresponding textures. The rock of the Utley area is a metarhyolite, at Berlin a rhyolite-gneiss, and in the Waushara area a granite. Analyses of the rocks of the three areas show a close similarity in chemical composition, and it is believed that the rocks represent phases of a single parent magma. The rocks have been metamorphosed to different degrees, and the results of the metamorphism, particularly of the feldspars, are described in detail.

The crystalline rocks are unconformably overlain by flat-lying Potsdam and Ordovician sediments. From their similarity in composition to the Baraboo volcanics, which are considered to be of Keweenawan age, it is believed that they belong to the same province, and are therefore of Keweenawan age.

[1] A contribution to the geology of the pre-Cambrian rocks of the Fox River Valley, Wis., by SAMUEL WEIDMAN: Bull. Wis. Geol. & Nat. Hist. Surv., No. III, 1898, pp. 63.

Norton,[1] in a description of the artesian wells of Iowa, discusses the attitude of the Algonkian floor. In the northwestern part of the state the Algonkian outcrops as the Sioux quartzite. From here it sinks rapidly to the south and east, and is discovered near the area of its outcrop only by the steep wells at Sioux City, Hull, and Le Mars. In the east-central part of Iowa is a slight elevation of the Algonkian floor, disclosed by the artesian well at Cedar Rapids. In Wisconsin the Algonkian outcrops as the Baraboo quartzite, a rock similar to the Sioux quartzite. From this outcrop the Algonkian sinks gently to the southwest, as it is reached by the drill at Lansing, Iowa. At no other place in Iowa has the drill gone deep enough to reach the crystalline rocks.

Comment.—The connection of the crystallines reached by the drill with the Algonkian outcrops of Iowa and Wisconsin is conjectural, and perhaps it would be better not to assume that such crystallines are all Algonkian. However, the observations are of interest as showing the attitude of the ancient crystalline floor, whether Archean or Algonkian.

Beyer[2] maps and describes the part of the Sioux quartzite formation exposed northeast of Sioux Falls in sections 10, 11, 14, 15, 22, and 23, T. 102 N., R. 48 W., South Dakota. The quartzite dips from 3° to 7° to the southwest. An accurate estimate of the thickness may not be given, but 1500 feet is a liberal one.

Slate is exposed in the area in isolated outcrops, but never in contact with the quartzite. In composition it corresponds very closely to the quartz-slate of Irving and Van Hise.[3] Intruding the slate are diabase dikes, which have followed the bedding.

The relations of the slates and quartzites cannot here be ascertained. However, from the relations of the two outside of the area it is believed that the slates are the upward continuation of the quartzite, and that they have been removed in large part.

The age of the Sioux quartzite is believed to be pre-Cretaceous. Its reference to the Huronian may be supported by the following facts: The lithological characters of the quartzite are identical with those of

[1] Artesian wells of Iowa, by W. H. NORTON: Geol. Survey of Iowa, Vol. VI, 1897 (The Algokian, pp. 139–140).

[2] The Sioux quartzite, and certain associated rocks, by S. W. BEYER: Iowa Geol. Survey, Vol. VI, 1897, pp. 69–112.

[3] The Penokee iron-bearing series, by R. D. IRVING and C. R. VAN HISE: Tenth Annual Rept. U. S. Geol. Survey, 1890, p. 370 et seq.

the Baraboo quartzite in Wisconsin, which has been referred by Irving and Van Hise to the Huronian. The diabase intruding the slate, supposed to be the upward continuation of the quartzite, is strikingly similar to intrusives which are peculiar to the Huronian in the Lake Superior region.

Frazer[1] sketches the geology of an area in the vicinity of Galena, in the Northern Black Hills of South Dakota. Mica-schists, thought to be upper members of the Archean, are found striking northeast-southwest, and dipping at angles from 38° to 85°. They are generally micaceous and coarse-grained, but vary greatly, sometimes passing into nacrite- or hydromica-schist, and sometimes, though more rarely, assuming a heavily bedded character reminding one of gneiss.

Todd[2] reports on a section across the Black Hills from Rapid City westward. The alternating slate and quartzite beds of the Algonkian were found to be folded in a most intricate fashion. A number of the folds were worked out. In most cases the lamination and stratification seem to correspond in direction.

Comment.—The last observation differs from one made by Van Hise, who, as a result of work done in 1890, concluded that the prominent foliation of the Black Hills is independent of the bedding, and as a rule cuts across it.

Griswold[3] describes the geology of Helena, Montana, and vicinity.

Middle Cambrian, or Flathead, quartzite forms an important part of the ridge stretching from Helena southeast to Montana City, and northwest, west, and south around Mount Helena. The sedimentary rocks underlying most of the area of the city, on the north side of this Cambrian quartzite, are classed as Algonkian. The Algonkian rocks vary from clay-slates to micaceous, sandy, or calcareous slates, which often become quartzites or limestones. The Algonkian slates seem to conform to the overlying strata in the dip of their beds. As there are many small folds, it is difficult to determine the thickness; 5000 feet does not seem too large a total.

Gilbert[4] maps and describes the geology of the Pueblo quadrangle,

[1] Notes on the Northern Black Hills of South Dakota, by PERSIFOR FRAZER: Trans. Am. Inst. Min. Engineers, Vol. XXVII, 1898, pp. 204–228.

[2] Section along Rapid Greek from Rapid City westward, by J. E. TODD: South Dakota Geol. Survey, Bull. No. 2, 1898, pp. 27–40.

[3] The geology of Helena, Montana, and vicinity, by L. S. GRISWOLD: Journal of the Association of Engineering Societies, Vol. XX, 1898, pp. 1–18.

[4] Geol. Atlas of the U. S., Pueblo folio, No. 36, by G. K. GILBERT: U. S. Geol. Survey, Washington, 1897.

including part of Pueblo county and the southeast corner of Fremont county, Colorado. Archean rocks occupy two small tracts in the southwestern part of the quadrangle. The more abundant kinds of Archean rocks are mica-schist, mica-gneiss, and granite. The schists and gneisses strike north to northwest, and are nearly vertical. Their origin is not known. The granite is intrusive in the schists and gneisses.

The Archean rocks are overlain unconformably by Paleozoic and Mesozoic sediments.

Lakes[1] sketches the geology of the Gunnison gold belt in Gunnison county, Col., from the Cebolla River on the west to the head of Taylor Park and the Sawatch range on the east. The northern part of area is included in the granitic system of the Sawatch range. The southern part is occupied by schists and gneisses, underlain by coarse massive granite. The schists and gneisses are of pre-Cambrian age, but whether Algonkian or older has not been determined. The contact of the schists and gneisses with the underlying granite is an eruptive one, the granite containing fragments of the schist, giving the impression that the schists had been floated up on an underlying molten or semi-molten sea of granite. Cutting the schists are occasional dikes of diabase and possibly basalt and andesite, and resting on the eroded edges of the schists are various later overflows of andesitic breccia, rhyolite, trachyte, and basalt.

Aguilera[2] gives a synopsis of the geology of Mexico. The most ancient, or Azoic, rocks are granites, gneisses, and schists, presenting many variations. They extend lengthwise along the Pacific coast, forming a narrow band, interrupted in places, and sending ramifications toward the central part of the country, in some places almost to the eastern coast. They occupy the southern part of the state of Puebla, a part of the Sierra Madre Mountains in Chiapas, and extensive portions of Oaxaca and Guerrero; they are found also in Zacatecas, around Fresnilo; in Guanajuato, in the vicinity of the capital; in Sinaloa, around the crests of the Sierra Madre; in Sonora, in its northwestern and western parts; in lower California, where

[1] Sketch of a portion of the Gunnison gold belt, including the Vulcan and Mammoth Chimney mines, by ARTHUR LAKES: Trans. Am. Inst. Min. Engineers, Vol. XXVI, 1897, pp. 440–448.

[2] Sinopsis de Geologia Mexicana, by JOSE C. AGUILERA: Bol. del Inst. Geol. de México, Nums. 4, 5, & 6, 1897, Part II, pp. 189–250. With geol. maps.

they constitute the central Cordilleran axis of the peninsula; in Vera Cruz, in its western region, limited by Puebla, in the canton of Zongolica.

In the southern part of Puebla, and in Guerrero and Oaxaca, where the greater part of the exposures occur, the sequence is as follows, from the base up: (*a*) Porphyritic gneiss, similar to augen-gneiss, at the base losing its lamination and passing into a kind of granite. (*b*) Phyllite-gneiss, resting upon, and grading below into preceding beds. (*c*) Very abundant mica-schist, in some places garnetiferous, and in perfect conformity with the phyllite-gneisses. (*d*) Phyllites, very argillaceous in the upper part, and showing gradual diminution in the proportion of clay toward the base. In accordance with this change of composition, the structure varies from perfectly schistose to laminated, and finally to stratiform.

After the deposition of the argillaceous phyllites, and before the termination of the Paleozoic, there have occurred numerous eruptions, in order of age as follows: Granite-gneiss, granite, granulite, hornblende granite, pegmatite, greisen, and diorite.

Comment.— The ancient rocks are mapped as Azoic, and in the text are described as Archean and Primitive, so that these three terms are used in the same sense, to cover all rocks below the Paleozoic. The pre-Paleozoic rocks are both sedimentary and igneous, and not improbably may represent the Algonkian as well as the Basement Complex.

C. K. LEITH.

MADISON, WIS.

Reviews

Geology of the Yellowstone National Park. Part II. Descriptive Geology, Petrography, and Paleontology. By ARNOLD HAGUE, J. P. IDDINGS, W. H. WEED, C. D. WALCOTT, G. H. GIRTY, T. W. STANTON, and F. H. KNOWLTON. Washington: Government Printing Office, 1899. Pp. xviii + 893, 121 plates and 4 figures. Monograph XXXII of the United States Geological Survey.

This compendious monograph is about equally divided between petrography and paleontology, having about 440 pages of text in each division, and of the 121 plates 62 are given to fossils, and 59 and the four figures to petrography and geology. Of the fourteen chapters Iddings furnished seven on the petrography, Iddings and Weed two on the geology, Weed and Hague each one on the geology. Walcott's work on the Cambrian fossils and Girty's on the Devonian and Carboniferous go into one chapter. Stanton furnishes one on the Mesozoic fossils and Knowlton one on paleobotany.

The first chapter, by Iddings and Weed, is on the descriptive geology of the Gallatin Mountains, which mountains extend eighteen miles within the boundary of the park. The diversity of the geological features in this area is remarkable. The sedimentary rocks begin with the Cambrian and range through the Silurian, Devonian, Carboniferous, and Juratrias into the Laramie division of the Upper Cretaceous. Cutting through the sedimentary series are intrusions of igneous masses in the form of laccoliths, sheets, and dikes. The sedimentary rocks are slightly folded and strongly faulted. Extensive erosion has exposed large areas of the rocks in their structural relations. To still add to the diversity, the surface has been glaciated.

The second chapter describes the intrusive rocks of the Gallatin Mountains. These consist mainly of fine-grained, aphanitic masses, mostly porphyritic and andesitic in character. The Indian Creek laccolith is hornblende-mica-andesite-porphyry. The Bighorn Pass sheet

consists of kersantite of complex composition; the Gray Mountain mass and connected sheets consist of andesite and andesite-porphyries. The Mount Holmes bysmalith, Gallatin River laccolith, and the Bunsen Peak mass are composed of dacite-porphyry.

Chapter three deals with Electric Peak and Sepulchre Mountain, which are described as parts of a Tertiary volcano faulted across the neck with a vertical throw of more than 5000 feet. The deeper parts of the volcano consist of sedimentary strata cut by dikes, sheets, and the stock or conduit of the volcano. The ejected breccia and lava flows, along with the upper portion of the conduit, make up Sepulchre Mountain. The andesitic lavas of Sepulchre Mountain change to diorites and porphyries in Electric Peak. Rocks with the same chemical composition in one place crystallize into diorites and in another place form andesites. Both types are illustrated by photomicrographs and photographs. Maps and section illustrate fully the relations of the different rocks.

The northern end of the Teton range, which occurs in the southern part of the park, is described at length in the next chapter. This range is made up of a nucleus of crystalline schists and gneisses, which are overlain by flexed and faulted Paleozoic and Mesozoic strata. The eroded edges of these old sedimentary rocks were covered with volcanic basic breccias and after another period of erosion an extensive outflow of acidic lava covered the whole area and still conceals the northern extremity of the Teton Mountain.

Mr. Hague, in chapter five, describes the irregular diversified mountainous area known as Huckleberry Mountain and Big Game Ridge. It lies in the southern part of the park and in the Forest reservation and consists of a number of northwest-southeast ridges, composed mostly of Mesozoic rocks. The Cretaceous sandstones are the prevailing rocks, but small areas of older strata are exposed. The rhyolites of the park plateau abut against the slopes of the upturned edges. Besides Huckleberry Mountain and Big Game Ridge, there are other elevations known as Wildcat Peak, Bobcat Ridge, Chicken Ridge, and Two Ocean Plateau. The principal igneous rocks in the area are dacites, surrounded by apparently younger rhyolite. In the gorge of the Snake River the Madison limestones, Teton sandstones, Ellis limestones, and shales are exposed. The Snake River hot springs occur near the contact of the rhyolite with the limestones. The travertine deposits around the springs resemble those around the Mammoth Hot Springs

and the lime is derived from the Madison limestone. The Laramie strata are exposed near the base of Pinyon Peak, as shown by the characteristic Wolverine flora. The conglomerate of Pinyon Peak is probably Eocene, as it underlies the basic breccias of the Absaroka range and overlies unconformably the Laramie sandstones. Outlet Canyon, the picturesque gorge cut through Chicken Ridge, at one time served as an outlet into Snake River for the waters of Yellowstone Lake. The Yellowstone Canyon now furnishes an outlet for these waters into the Atlantic, instead of into the Pacific. Two Ocean Plateau, which rises 10,000 feet above the sea level, forms a part of the Absaroka Range. It is made up of volcanic breccias and tuffs.

Chapter six describes the southern end of the Snowy range, which forms the northeast corner of the park. It consists of a broad core of crystalline rocks, bordered by Paleozoic rocks, which dip away from the crystalline axis. Detailed sections of the Paleozoic sedimentary rocks are given, but the igneous rocks are described in other chapters.

Chapter seven is especially interesting to petrologists, as it describes in detail the structural features and petrographic characteristics of a dissected volcano in the Crandall Creek basin. It lies on the border of the park forest reservation and east of the park proper. The great value to petrology lies in the clear delineation of the inside of a volcano, and in giving additional field evidence of the gradation of coarsely crystalline so-called Plutonic rocks into the glassy eruptives. "The coarsely crystalline gabbros and diorites, with smaller bodies of granite, exposed for a height of 3000 feet, are plainly seen to have been intruded into a vast accumulation of basaltic tuff and scoriaceous breccia. From this coarsely crystalline mass as a center, dikes of fine-grained rock penetrate the surrounding lavas in all directions, the dike rocks becoming fine-grained rapidly as they leave the once heated core. They form a network of branches which connect the outlying aphanitic and characteristically volcanic rocks with the more crystalline dikes near the core which finally merge into the granular body of the gabbro and dorite." The whole forms one complex network so closely interwoven that the gabbros of the core are as truly volcanic as the glasses on the surface. The volcano has built itself upon a ridge of eroded Paleozoic rocks, and beneath the volcano are remnants of Eocene breccias and lava flows.

The next chapter treats of the Absaroka range which consists mainly of volcanic breccias with smaller quantities of massive flows. It contains

an account of their field occurrence and distribution, and a systematic description of their mineralogical composition and characteristics. The oldest rocks occur at the north end and consist of acid breccias found in remnants underlying early basic breccias. The former consist mainly of hornblende-andesite and hornblende-mica-andesite. The basic breccias consist of pyroxene-andesite, passing upward into basalt. Upon these were thrown other acid breccias, similar in composition and appearance to the earlier ones. These grade upwards into later basic breccia, consisting of andesites with less basalt than occurs with the earlier flows. This last basic breccia forms the southern portion of the range within the park and also the Two Ocean Plateau. Remnants of surface flows of massive andesite form the summits of Mt. Stevenson, Mt. Doane, Colter Peak, and several prominent mountains south of Sylvan Pass.

Chapters nine, ten, and eleven discuss different classes of the volcanic rocks. The Absarokite-Shoshonite-Banakite series consists of certain basaltic and other rocks associated with andesitic breccias and basalt flows which have considerable orthoclase and a comparatively high percentage of potash. They occur as lava flows and dikes in various localities. They have been classified according to their chemical and mineral composition.

The rhyolites in the park are almost wholly extrusive lavas of uniform chemical composition, but differing widely in color, texture, and megascopic habit. The mode of occurrence, and the microscopic features of phenocrysts, spherulites, lithophysae, are described in detail, and beautifully illustrated. The modifications of crystallization, lamination and the formation of pumice are referred to heterogeneity of the molten magma, especially with reference to the amount of vapors contained in it. In some places basalt appears to have been inclosed and partly fused by the rhyolite.

The recent basalts are distinguished from the early brecciated ones by being ophitic and non-porphyritic. They overlie the rhyolite in most cases, but in some places they occur beneath it, and in some places between the older and younger sheets of rhyolite.

With chapter twelve begins the paleontologic part of the work. The Director of the survey describes the Cambrian fauna from which twenty-one species have been obtained. Several of these are new, and are here described and illustrated for the first time. No fossils of undoubted Silurian age have been obtained. The Devonian is

represented in the Three Forks limestone. A varied but wholly Lower Carboniferous fauna has been obtained from the Madison limestone.

In chapter thirteen Mr. Stanton describes the Mesozoic fossils. These were obtained from the Gallatin range, near Electric Peak, Teton range, in the vicinity of Wildcat Peak and Huckleberry Mountain, and from the Cretaceous ridges in the southern end of the park and Yellowstone Forest Reserve. There are seventy-eight invertebrates, one of which is supposed to be of Triassic age, forty-six are Jurassic, and thirty-two are Cretaceous. The fossils are mainly from the Ellis division of the Jurassic and the Colorado of the Cretaceous.

The last chapter, by Mr. Knowlton, on the fossil flora, is a long one, covering 233 pages, besides 45 plates of illustrations. The Mesozoic flora is confined to the Laramie sandstones of the Cretaceous, and is found on Mt. Everts, near Mammoth Hot Springs, and at the base of Pinyon Peak, near the head of Wolverine Creek. The Tertiary flora is quite varied, and full of biological interest. On comparing it with the present it signifies great climatic changes since the Miocene. It is found in numerous localities associated with the breccias and silts of the igneous rocks, where the muds and silts furnished a soil favorable to plant growth. The Tertiary fossil flora embraces about 150 forms in thirty-three orders. The interesting fossil forest trees of Specimen Ridge are illustrated with photographs of the trees in the field and enlarged microscopic sections showing the cellular structure.

The petrographical and paleontological features of the Yellowstone National Park are certainly described in great detail, and the monograph will no doubt prove to be a valuable handbook to scientists, especially to those visiting the region.

T. C. H.

Report on the Geology and Natural Resources of the Area included by the Nipissing and Temiscaming Map Sheets, comprising portions of the district of Nipissing, Ontario, and of the county of Pontiac, Quebec. By ALFRED ERNEST BARLOW. Geological Survey of Canada. Part I, Annual Report. Vol X, 1899, pp. 302.

This report, accompanied by two well-executed maps on a scale of four miles to the inch, and covering an area 6912 square miles of the northern Protaxis of the Dominion of Canada, is a valuable addition to the literature of the pre-Cambrian of North America and is a further

installment of the work which is being systematically carried forward by the Dominion Geological Survey on these older rocks. The two maps, constituting what are known as sheets Nos. 131 and 138 of the Canadian Series, lie in the Upper Ottawa district along the border of the two Provinces of Quebec and Ontario, and comprise portions of both. Lake Nipissing and Lakes Temagami, Temiscaming, and Keepawa, as well as many smaller bodies of water, are included in the area, and afford along their shores especially good opportunities for the prosecution of geological work.

After presenting a general account of the early explorations in this region, some of which date back almost to the time of the earliest settlement of the country by the French, and of previous surveys, the physical features of the country are described. The area is a great uneven, or gently undulating, rocky plateau, sloping somewhat to the east and southeast, having a general elevation of 900 to 1200 feet above sea level, the level being so nearly uniform that hills 50 to 100 feet higher are conspicuous topographical features. This peneplain is traversed in a north and south direction along one line by a very deep and narrow rocky gorge, in which lie Lake Temiscaming and the Ottawa River. The hills, or cliffs, rise to a height of 400 to 600 feet from the water on either side, while the water of the lake is 400 feet deep; the bottom of the gorge being filled with a fine silt. The depression is thus at least 1000 feet deep and represents a great canyon similar to those which are found on the margin of the northern Protaxis at so many other points. Several smaller rivers also occupy similar depressions. "The detailed examination of the region, however, amply demonstrates that the sculpturing to which the surface owes its present configuration was practically completed long before the advent of the glacial epoch, and that the main valleys, especially those of the Ottawa and Mattawa rivers, were in existence long prior to the deposition of the Palaeozoic sediments." With the exception of some comparatively small areas occupied by Palaeozoic outliers, ranging in age from Black River to Niagara, the district is underlain by rocks of Laurentian and Huronian age. The Laurentian, with the exception of a few small occurrences, is represented exclusively by the fundamental gneiss, a mass of granitic and dioritic rocks, usually possessing a foliated structure in which are many streaks, bands, or inclusions of basic character, allied to diorites or diabases in composition, and representing either basic segregations from the granitic magma or portions of

basic intrusions caught up in it. This fundamental gneiss, it is believed, probably represents the original crust of the earth which has undergone successive fusions and re-cementations before reaching its present condition. In placing these rocks at the base of the series it is not intended to assert that they stand for any distinct or prolonged period of geological time, nor to affirm that these rocks, in their present condition and with the foliation which they now possess, antedate those of the Huronian system. This, as is shown, is not the case in many, or even probably in most, instances.

The chemical and mineralogical composition of the gneisses, as well as the character and origin of their foliation and the genetic relation of their associated pegmatites, are considered at length, and many interesting facts brought forward which cannot here be further discussed.

The Grenville series, so extensively developed further south, is in this northern area represented only by a few very small and unimportant occurrences of highly crystalline limestone and a single occurrence of gneiss. They occur isolated from one another and surrounded by fundamental gneiss on every side, and are referred to the Grenville series on account of their identity in petrographical character with the areas of this formation immediately to the south.

The district also includes large tracts of country underlain by pyroclastic and epiclastic rocks, forming a northeasterly extension of the development of the "typical" Huronian area on the north shore of Lake Huron. At one place on Lake Temiscaming, these Huronian rocks are found resting upon the floor of fundamental gneiss on which they were originally deposited, and of whose detritus they are made up, everywhere else the fundamental gneiss has been refused or softened and penetrates the superincumbent Huronian. The total thickness of the Huronian in the area is about 1800 feet, made up as follows: 1. Breccia-Conglomerate, 600 feet. 2. Shales and slaty greywackes, 100 feet. 3. Quartzose grit or Arkose, 1100 feet. Associated with these Huronian sediments are numerous intrusions of gabbro and diabase, some of which pass over gradually into flesh-red granites, representing, it is believed, portions of one and the same magma.

No attempt is made in this report to correlate the Grenville series and the Huronian of the area, as the facts are insufficient to warrant the attempt. And it may be remarked incidentally in this connection that a statement, made on page 415 of the current volume of this

JOURNAL, in reviewing some other recent papers on the Canadian pre-Cambrian, is scarcely correct. The statement is as follows:

"The succession and correlation proposed in the above papers by Adams and Barlow and by Ells are fundamentally different from the traditional one which has been held in Canada for many years. The first departure is in placing the Grenville and Hastings series as equivalent to the Huronian."

In the papers in question this correlation was not definitely made, but it was stated in reference to the Hastings series that "both lithologically and stratigraphically the rocks bear a striking resemblance to rocks mapped as Huronian in the region to the north and north-east of Lake Huron, and it seems very likely that the identity of the two series may eventually be established. The two areas, however, are rather widely separated geographically, and the greatest care will have to be exercised in attempting such a correlation."[1]

The further statement made by the reviewer that "Ells places with the Huronian all the sedimentary rocks of Eastern Canada" is also manifestly inaccurate, seeing that while it might terminate the controversy concerning the upward extension of the Huronian to include in that system the whole Palaeozoic succession, Ells cercainly did not advocate this course.

The Palaeozoic outliers in this area and especially that of Niagara age are of exceptional interest. Geographically this outlying patch of Niagara is so widely separated from any other locality where rocks of this age are now known to exist, that it has been a question as to whether it was formerly connected with the occurrences about Hudson Bay or with those about Lake Ontario. The strata are highly fossiliferous and the palaeontological evidence presented seems to prove that the seas in which the Niagara sediments of the Winnipeg basin and of Hudson Bay were deposited were practically continuous, while both were separated from the Temiscaming basin and the region to the southwest.

The Pleistocene history of the region seems to consist of a period of glaciation by a great ice-sheet, followed by a profound submergence, during which time the ocean invaded a large portion of the Ottawa valley forming a marine gulf rivaling in extent the similar invasions of the sea in Palaeozoic times. The direction of motion of the ice varies from S 7° W to S 18° W.

[1] American Journal of Science, Vol. III, March 1897, p. 177.

The report also contains much information concerning the fauna, flora, and timber resources of the district, and has appendices giving lists of elevations and catalogues of the Palaeozoic fossils.

FRANK D. ADAMS.

The Paleozoic Reticulate Sponges Constituting the Family Dictyospongidae. By JAMES HALL and JOHN M. CLARKE.

More than a year ago volume one of the Fifteenth Annual Report of the New York state geologist made its appearance. In the introduction to this report several papers were announced which were not included in the volume, one of them being a monograph of the Dictyospongidae. It is this monograph which has now been published as volume two of the report above mentioned. It also appears in another binding as Memoir II of the New York State Museum. Unfortunately the annual report of the state geologist does not contain the complete monograph, the descriptions and illustrations of Carboniferous species being omitted. This monograph has long been in preparation by Drs. Hall and Clarke, and the printing of it had only been begun at the time of Dr. Hall's death.

The dictyospongidae are an extinct family of hexactinellid sponges, whose nearest living representative is the delicate glass sponge, *Euplectella*, commonly known as the "venus flower basket." They lived in greatest abundance during later Devonian and early Carboniferous time, though their most ancient representatives occur far back in the Silurian. Their fossil remains are especially abundant in the sandstones of the Chemung formation in western New York, several extensive colonies of them having been discovered as they grew upon the ancient sea bottom. Notable collections of them have also been made in the Waverly sandstones in Ohio, and in the Keokuk shale at Crawfordsville, Ind., and from the last locality only, have specimens been found in which the spicular skeleton of the sponge has been preserved.

The variety of forms assumed by these interesting sponges is wonderful, and the earlier observers were at a loss to know where to place them in the zoölogical classification. Before their sponge nature had been definitely established by Whitfield in 1881, they had been described as cephalopods and as marine plants. In life these organisms must have been most beautiful objects, "with their manifold variety of

graceful and striking shapes, they were not the somber bodies we find them to be in the rocks, but formed the most delicately woven fabrics of glass, latticed vases, urns and cups of the rarest delicacy and beauty. They must have been, when denuded of their sarcode, among the most exquisite structures of the past, as their descendants are of the present. Nothing, for example, could have surpassed the graceful filigreed chalice of *Botryodictya ramosa*, with its slender, tufted pedicel expanding above with a cup ornamented with pendant pouches."

In the list of genera and species, twenty-eight genera and one hundred and twenty eight species of these organisms are recognized, a great majority of them being here described for the first time. These descriptions of genera and species, with the introductory portion of the volume, fill two hundred quarto pages of text, and they are illustrated by seventy finely executed lithographic plates.

S. W.

Geological Report on Isle Royale, Michigan. By ALFRED C. LANE. Geological Survey of Michigan, Vol. VI, Part I. Lansing, 1898, pp. i + 281. 16 plates, 29 figures, 13 tables.

The report begins with a historical sketch of the mining operations from pre-historic times to the present. This is followed by a description of the method of constructing cross sections of the country from drill records, and this by an account of the succession of rocks forming the island, involving a detailed statement of the rocks traversed by sixteen drill holes. The results are compared with Irving's cross sections of Keweenaw Point, and the conclusion reached that there is represented on the Isle Royale practically the whole of the copper range as it exists from the Central mine to Portage Lake. A comparison is made with the Minnesota section with less definite results.

The portion of the report of more general interest is that which treats of the grain of rocks, both the theoretical discussion and the application of the theory to the rocks under investigation. The discussion opens with the consideration of conditions that affect cooling of molten magmas. Laws controlling the loss of heat are expressed mathematically, and diagrams are constructed exhibiting rates of cooling under various conditions. Deductions regarding the variations

in the grain of rocks corresponding to these conditions are exceedingly important and interesting. Some of the theoretical deductions are as follows: (1) After the temperature at the center of an intruded magma has fallen about one fourth of the interval between the initial temperature and the marginal temperature, the rate of cooling at a given temperature is the same for all parts of the sheet. (2) If the initial temperature (of intrusion) and conditions of cooling are such that a considerable time elapses before any part of the sheet reaches the point of solidification, the rate of cooling will be the same at all points, and, so far as the grain is dependent on it, there will be no change of grain, but the grain will be uniform from margin to center. (3) The hotter the dike or sheet initially, the less will be the width of the marginal zones of gradually finer grain; also, the hotter the country rock, the less pronounced will be the marginal zone of finer grain. (4) The time of cooling varies as the square of the thickness of the dike or sheet, so that a dike 200 feet thick will cool four times as slowly, other things being equal, as a dike 100 feet thick. (5) Before the center (of an intruded mass) begins to cool off, the time required for a given loss of temperature for any point will vary as the square of its distance from the margin.

In applying the theory to the rocks examined it was found that some minerals, such as augite and feldspar, conformed fairly with theoretical requirements. In the case of sheets which have solidified before the center had appreciably cooled, it was found that "the area of cross sections or surface of the grains varies directly as the slowness of cooling." Again, "the linear dimensions of the augite patches (in the ophites, are directly as the distance from the margin."

With regard to the effect of chemical composition on grain, it is announced that "other things being equal, the greater the abundance of its constituent molecules, the coarser the grain of any mineral."

In conclusion, Dr. Lane ventures the prophecy "that it will prove widely true that superficial (extrusive) basic rocks are characterized by an increase of grain to near the center, while deep-seated basic rocks have a broad central zone of nearly uniform grain." He remarks in connection with the question of the effect of geological environment upon rocks that "it must also be remembered that the possession and loss of gas by diffusion follow the same laws as the possession and loss of the imponderable 'caloric,' while the possession of gas may greatly lower the temperature of solidification as glass."

The report closes with chapters on the petrography of the rocks; on the topography and Quaternary geology; the stratigraphy; and the chemical problems which are treated briefly. The last chapter is devoted to diabases, probably Keweenawan, intrusive in the Huronian. Among various interesting observations made in connection with these rocks is the conclusion that the micropegmatitic (micographic) intergrowth of quartz and feldspar found in some of them is undoubtedly a primary cystallization, and not a result of alteration in the rock.

J. P. I.

The Department of Geology and Natural Resources of Indiana. Twenty-third Annual Report. By GEORGE H. ASHLEY, Ph.D., Assistant State Geologist.

The report consists of 1741 pages, the first 1573 of which are devoted to the coals and coal area of the state. The state geologist, Mr. W. S. Blatchley, is to be congratulated on having secured, for this work of such importance to the state, the services of so painstaking and energetic a worker as Dr. Ashley.

The primary idea of the author seems to have been to make the report of the greatest possible value to those interested in the coal industry. Nevertheless it discloses much that is new concerning the structure of the southwestern part of the state, and throws light on the physical conditions that attended the formation of the Coal Measures of the eastern interior coal field.

Instead of using the letters of the alphabet to designate the different coal beds, as is done by Mr. Cox in the Seventh Annual Report, or Arabic numerals, as was done in the Illinois and Kentucky reports, the author has made use of Roman numerals, each of which denotes a division of the Coal Measures. There are eight of these divisions, numbered from below upward. In those localities, where a division includes more than one coal bed, the small letters of the alphabet are brought into use. For example, the three coals of Division v are designated v, va, vb. This method seems to present the advantage of at all times denoting the exact horizon under consideration, and of locating the beds of small area.

The organization of the volume divides it into four parts. Part I dealing with the Geology of Coal; Part II, with the General Geology

of the Coal Measures of Indiana; Part III, with the Detailed Geology of the Indiana Coal Field; and Part IV, with Mines, Mining, and the Utilization of Coal. In Part III the method of treatment is by counties.

Probably the best feature of the report is to be found in the excellent illustrations, which consist of 986 figures, 91 plates, and 7 maps. Especially are the maps and the accompanying sections to be commended.

The latter part of the volume is devoted to reports of the inspector of mines and the natural gas supervisor.

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United States Geological Survey. Monograph XXXI. Geology of the Aspen Mining District, Colorado, with Atlas. JOSIAH EDWARD SPURR. Samuel Franklin Emmons, geologist in charge.

The monograph is primarily concerned with the economic interests of the Aspen district. But it also contains much that is of general scientific interest. Mr. Emmons contributes the introduction, but the body of the monograph is the work of Mr. Spurr. The volume is profusely illustrated and the accompanying atlas contains sheets giving the general geology and topography of the district, besides eight special sheets giving the detailed geology of limited areas. It also contains numerous sections constructed on an elaborate scale, which make the complex faulting intelligible. Both the monograph and its accompanying atlas exemplify the magnificent execution characteristic of the United States Geological Survey.

Great interest attaches to the author's study of faults as set forth in this work. Aspen seems to have furnished a field quite worthy of his best endeavor. Some of the sheets presented in the atlas seem like inextricable puzzles; but this special student of faults straightens out the "crazy-work" in an admirable way and makes it all intelligible. It is of interest to note the fact that movement along some of the faulting plains is taking place at the present time at a rate which requires recognition in the practical operations of mining.

Under "Chemical Geology" some observations are given which throw light on the vexed question of dolomization. The origin and change of ores is also discussed.

W. T. LEE.

Geological Survey of Georgia. W. S. Yeates, State Geologist. *Bulletin No. 7, A Preliminary Report on the Artesian-Well System of Georgia.* By S. W. MCCALLIE, Assistant Geologist. State Printer, Atlanta, Ga., 1898, pp. 214.

One of the significant signs of growing wisdom in the administration of state surveys is the increased attention given to common resources of wide interest as distinguished from rich deposits of immediate value to a fortunate few only. Among these resources of common interest is the water supply which admits of successful treatment on a scientific basis, whether in the form of flowing wells or otherwise. In real importance it transcends many of the more impressive subjects. The present treaties is an excellent expression of this commendable policy. The first thirty pages are devoted to a clear exposition of the essential conditions of successful artesian wells and practical considerations relative to them. This is well illustrated. The rest of the volume is devoted to the special consideration of the artesian wells of Georgia, in which much data of general geological interest is incidentally included. Large artesian resourses are shown. While full data are not obtainable, it is clear that notable improvement in public health has resulted from the use of these wells. T. C. C.

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